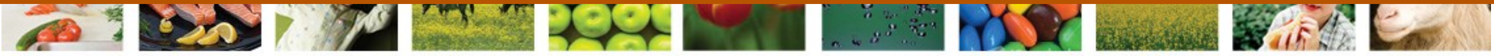

Vitenskapskomiteen for mattrygghet

Norwegian Scientific Committee for Food Safety

Comparison of organic and conventional food and food production

Part I: Plant health and plant production

Opinion of the Panel on Plant Health and the Steering Committee of the Norwegian Scientific Committee for Food Safety

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Summary

Organic plant production in 2012 covered 50 200 ha which is 5.1% of the total agricultural area of Norway. The country is on the northern frontier for commercial plant production with short growing season, low summer temperature, and in some districts precipitation above the optimum for crops. However, many hours of daylight during the summer months are positive for plant production. Very few Norwegian studies have compared organic and conventional plant production. Therefore, the evaluations of nutrient contents, plant health and environmental contaminants are mainly based on scientific publications from other countries of Europe and North America. The main sources of uncertainty in the evaluation are differences in climate, soil types and varieties cultivated in Norway and in the countries were comparative studies of organic and conventional agriculture have been performed.

Plant health

Most studies conclude that crop losses due to plant diseases, plant pests and weeds are higher in organic than in conventional production. The most probable explanation for these differences is that the control methods available to organic farmers are less efficient than those used in conventional farming. Richness and abundance of pollinating insects and natural enemies of harmful insects are higher in organic than in conventional farming.

Plant pests

It is difficult to draw a general conclusion on the effect of organic farming vs. conventional farming on crop pests due to relatively few published studies. Higher damages due to insects and mites are expected in organic compared to conventional farming. Investigations of natural enemies of plant pests show that there is a tendency towards higher species richness and abundance in organic compared to conventional farming. More data are needed especially on single pest species in the major crops.

There appears to be no clear pattern with regard to prevalence of feeding groups of nematodes in organic and conventional farming systems. The crop plants may be more important for the nematode community than the management system.

Pollinating insects

Insect pollinators represent an ecosystem service in agricultural landscapes. Both species richness and abundance of pollinating insects and natural enemies of harmful insects are higher in organic than in conventional farming. Higher heterogeneity of landscapes and absence of pesticides in organic farming are the most likely reasons for the difference.

Plant diseases

Powdery mildew incidence seems to be lower in organic cereals. For other leaf diseases of cereals there are no consistent differences in incidence between the cultivation systems. Two studies reported on more root rot in organic then in conventional cereals, and two studies found no difference. Two studies found less *Fusarium* head blight in organic than in conventional cereals, while two studies reported on no difference between the cultivation systems.

Late blight is so severe on susceptible potato cultivars under organic cultivation that only resistant cultivars can be grown in climate with annual late blight epidemics. The limited number of comparative studies on other potato diseases does not provide sufficient data to conclude that are differences between the cultivation systems.

Apple scab is more severe in organic production, since less efficient control methods are available. For other apple diseases there are too few comparative studies to conclude that there are any differences in disease incidence between the cultivation systems.

Grey mould is a major challenge for strawberry growers. With few control methods available the yield losses from grey mould are larger in organic than in conventional cultivation. For other strawberry diseases there are too few comparative studies to conclude that the cultivation system will influence the disease incidence.

The few comparative studies on carrot and onion diseases in different cultivation systems do not provide sufficient data to conclude that there are differences in disease incidence between organic and conventional field vegetables.

Weeds

Most studies conclude that organic farming increases weed species richness. The densities of summer annual and biennial weed species are higher on organic than on conventional farms, and weed density and biomass on organic farms commonly exceed the level where the estimated benefit covers the cost of treatment (economic threshold). The most probable explanation for these differences is that the control methods available to organic farmers are less efficient than those used in conventional farming. Another reason is that on the organic plots no direct weed control measures were carried out in many studies. Perennial weed species, especially the subgroup creeping perennial weed species is another problem in organic farming.

Some studies conclude that proper use of weed harrowing in cereals may avoid yield losses caused by competition from annual weed species in organic farming. To optimize measures for non-chemical control of perennial weeds, knowledge of weed biology is crucial for determining the best method and timing of the operations. To successfully control both annual and perennial weeds in organic farming a variety of both preventive and direct measures must be included.

The crop cultivars developed before the advent of modern, high-input agriculture may be better suited to lower soil nutrients levels and elevated weed competition than the cultivars developed for conventional agriculture. Better crop rotation increases weed species richness in organic farming, while higher nitrogen levels in conventional farming reduces weed richness. Development of methods for improved weed control methods for organic farming has high priority.

Nutrients and bioactive substances

In general, there are small differences in content of nutrients, secondary plant metabolites, and other constituents in plants, except for organic fruit and berries were higher levels of dry matter, ascorbic acid and antioxidant activity have been found. In conventionally grown wheat there are commonly higher levels of protein than in organically grown wheat.

Nutrients in cereals

There are convincing data to conclude that in conventional wheat there are commonly higher levels of protein then in organically produced wheat. High protein content is important for the baking quality of wheat flour. Differences in nitrogen supply between organic and conventional agriculture is probably the reason for this discrepancy. For other nutrients, the literature is too limited for any sound conclusions to be drawn.

Nutrients and bioactive substances in potato

Dry matter and starch contents are higher in organic than in conventional potato. Higher nutrient levels in the soil support rapid growth of the potato tuber at the expense of dry matter and starch content in conventional farming. The levels of ascorbic acid, macro and trace elements do not differ between the cultivation systems. In most studies the nitrate content is higher in conventional than in organic potato due to higher soil nitrogen level in conventional than in organic farming.

Nutrients and bioactive substances in fruit

Most studies report organic apples have higher levels of dry matter, ascorbic acid, antioxidant activity than conventional apples. The results show a large variation within and between the different production methods.

Nutrients and bioactive substances in berries

Results from most of the included studies show that organic berries may have higher sensory quality and content of secondary plant metabolites with antioxidant activity and some minerals then conventional berries. In some of the studies there was no effect of the production system, while others found higher values in conventionally compared to organically produced berries.

Nutrients and bioactive substances in vegetables

For vegetables the results were variable and less clear. In some studies vegetables grown in organic production systems have higher content of some nutrients and secondary plant metabolites with antioxidant activity, while in other studies there was no effect of the growing system on the nutrients analysed. Also, the level of nitrate in some studies was lower and in other studies higher in organic compared to conventionally grown vegetables. Therefore, it is not possible to draw a clear conclusion on the effect of production system on nutrients and nitrate contents in vegetables.

Environmental chemical contaminants

Plant uptake of most organic chemical contaminants from soil is very low or negligible. Differences in organic contaminants in soil are probably mostly related to sources that are not influenced by organic and conventional practices. Due to high human consumption cereals and vegetables are important sources for dietary intake of heavy metals. The data do not provide basis for a firm conclusion on different levels of metals between organically and conventionally grown food plants.

Mycotoxin contamination

Contamination of cereals with *Fusarium*-mycotoxins is widespread. Results from comparison of mycotoxin contamination in organic and conventional cereals are variable. Most studies found no difference in DON content' and the majority of the remaining studies reported on lower levels of DON in organic than in conventional cereals. Most studies showed that organically produced cereals contained lower levels of T-2 and HT-2 toxin than conventionally grown cereals. Organic cereal farmers practice wider crop rotation, more ploughing, and they apply less fertilizer which gives lower plant density then on conventional farms. DON producing fungi are partly controlled by fungicides in conventional farming, while there are no approved fungicides for control of T-2 and HT-2 producing fungi.

Four studies showed higher mycotoxin contamination in organic than in conventional apple products, while seven studies reported no differences in contamination. The difference may be due to more efficient disease control in conventional orchards, which reduces the mycotoxin producing fungi in apple fruits.

Seed and seed potato quality

Only few comparative studies of quality in organic and conventional seed and seed potatoes have been published, and it is not possible to conclude on quality differences. In some studies a higher proportion of seed borne diseases were found in organic than in conventional seeds.

Keywords

Organic vs. conventional, plant health, plant production, crops, plant pests, nutrients, environmental contaminants, mycotoxins, seed quality, weeds

Norsk sammendrag

Plantehelse - planteproduksjon

Det var i 2012 økologisk planteproduksjon på 502 000 daa i Norge, noe som utgjorde 5.1 % av landbruksarealet. Landet ligger ved nordgrensa for kommersiell plantekultur med kort vekstsesong, lav temperatur gjennom sommeren og i noen områder nedbør over det optimale for plantedyrking. Men mange timer dagslys gjennom sommermånedene er positivt for vekst og planteproduksjon. Det er svært få norske undersøkelser som har sammenlignet økologisk og konvensjonell planteproduksjon. Derfor er vurderingene av næringsinnhold, plantehelse og miljøgifter i hovedsak basert på vitenskapelige publikasjoner fra andre land i Europa og Nord-Amerika. De viktigste grunner til usikkerhet i vurderingen er forskjeller i klima, jordbunnsforhold og sortsmateriale mellom Norge og de land som har gjennomført sammenlignende studier av økologisk og konvensjonell planteproduksjon.

Plantehelse

De fleste studier konkluderer med større avlingstap på grunn av plantesjukdommer, skadedyr og ugras i økologisk enn i konvensjonell produksjon. Den mest sannsynlige forklaringen på disse forskjellene er at bekjempelsesmetodene som økologiske dyrkere kan bruke er mindre effektive enn de som brukes i konvensjonell dyrking

Skadedyr på planter

Det er vanskelig å lage en generell konklusjon om effekter av økologisk og konvensjonell dyrking på grunn av relativt få publiserte studier. Det forventes mer skade av insekter og midd i økologisk enn i konvensjonell planteproduksjon. Undersøkelser av naturlige fiender til skadedyr på planter viser at det er en tendens til større artsmangfold og mengde i økologisk sammenlignet med konvensjonell dyrking. Det er behov for mer data spesielt om enkelte skadedyr i de viktigste kulturene.

Det er ikke noe tydelig mønster i mengde av nematoder i økologisk og konvensjonell dyrking. Vertplanten synes å ha større betydning for nematodefaunaen enn dyrkingssystemet.

Pollinerende insekter

Pollinerende insekter har stor betydning for økosystemene i kulturlandskapene. Det er større mangfold og mengde av pollinerende insekter og naturlige fiender til skadedyr i økologisk enn i konvensjonell plantekultur. Mer uensartede kulturlandskap og fravær av kjemiske plantevernmidler i økologisk dyrking er de mest sannsynlige forklaringene på disse forskjellene.

Plantesjukdommer

Det synes å være mindre mjøldogg i økologisk korn. For andre bladsjukdommer i korn er det ingen klare forskjeller mellom dyrkingssystemene. To studier fant mer fotsjuke i økologisk korn enn i konvensjonelt korn, mens to undersøkelser ikke fant noen forskjeller. To publikasjoner rapporterte om mindre aksfusariose i økologisk enn i konvensjonelt korn, mens to undersøkelser ikke fant noen forskjeller mellom dyrkingssystemene.

Tørråteangrepene er så sterke på mottakelige sorter i økologisk dyrking at bare resistente sorter kan dyrkes i klimasoner med årvisse tørråteangrep. Det begrensa antall sammenlignende undersøkelser av andre potetsjukdommer gir ikke tilstrekkelig grunnlag for å konkludere noe om forskjeller mellom dyrkingssystemene.

Angrepene av epleskurv er sterkere i økologisk dyrking, fordi bekjempelsesmetodene er mindre effektive. For andre eplesjukdommer er for få sammenlignede studier til å konkludere med at det er forskjeller mellom dyrkingssystemene.

Gråskimmel er en hovedutfordring for jordbærdyrkere. Med få bekjempelsesmetoder tilgjengelige er avlingstapene på grunn av gråskimmel større i økologisk enn i konvensjonell dyrking. For andre jordbærsjukdommer er det for får sammenlignende studier til å konkludere med at dyrkingssystemene betyr noe for angrepsgraden.

Få sammenlignende studier av gulrot- og løksjukdommer i ulike dyrkingssystem gir ikke tilstrekkelig med data til å konkludere at det er forskjeller i sjukdomsangrep mellom økologisk og konvensjonell grønnsakskulturer på friland.

Ugras

De fleste studier konkluderer med at økologisk dyrking øker mangfoldet av ugrasarter. Ugrasmengden øker innen alle biologiske ugrasgrupper, eksempelvis sommerettårige og toårige ugrasarter, på økologiske gårder sammenlignet med konvensjonelle. Mengde ugras på økologiske gårder vil ofte redusere avlingsnivå av kulturveksten og vil dessuten ofte også overskride nivået der beregnet gevinst overstiger kostnadene ved bekjempelse (økonomisk skadeterskel). Den mest sannsynlige forklaringen på disse forskjellene er at bekjempelsesmetodene som økologiske dyrkere kan bruke er mindre effektive enn de som brukes i konvensjonell dyrking. En annen forklaring er at det i f.eks. mange studier i korn ikke ble benyttet direkte tiltak mot ugras (eks. ugrasharving) mellom såtidspunkt og tresking på økologiske forsøksruter. Flerårige ugras, spesielt arter tilhørende undergruppen vandrende, flerårige ugras er et annet betydelig problem i økologisk dyrking.

Noen studier konkluderer med at optimal bruk av ugrasharving i korn ofte vil eliminere avlingstapene på grunn av konkurranse fra ettårige ugras i økologisk dyrking. For å optimalisere ikke-kjemiske tiltak mot flerårige ugras er kunnskap om ugrasbiologi avgjørende både når det gjelder valg av metode og tidspunkt for gjennomføring. For vellykket kontroll av både ettårige og flerårige ugras i økologisk dyrking er det nødvendig å bruke både forebyggende og direkte tiltak.

Sorter av kulturplanter utviklet før vi fikk moderne, høyintensivt landbruk kan være bedre tilpasset til lavere gjødslingsnivå og sterkere konkurranse fra ugraset enn sorter utviklet for konvensjonelt landbruk. Bedre vekstskifte øker ugrasmangfoldet i økologisk dyrking, mens høyere nitrogennivå i konvensjonell dyrking reduserer ugrasmangfoldet. Utvikling av metoder for bedre ugraskontroll i økologisk dyrking har høy prioritet.

Næringsinnhold og bioaktive stoffer

Generelt er det små forskjeller i næringsinnhold, sekundære plantemetabolitter og andre innholdsstoff i planter, med unntak av økologisk frukt og bær som har høyere innhold av tørrstoff, askorbinsyre og antioksidant-aktivitet. Konvensjonell hvete har gjennomgående høyere proteininnhold enn økologisk hvete.

Næringsinnhold i korn

Det er godt datagrunnlag for å konkludere med at konvensjonell hvete vanligvis har høyere proteinnivå enn økologisk dyrka hvete. Høyt protein-innhold er viktig for bakekvaliteten av hvete. Forskjellen i nitrogentilførsel mellom økologisk og konvensjonell landbruk er sannsynlig forklaringen på ulikt proteinnivå. For andre næringsstoffer er det for få studier til å trekke noen konklusjoner.

Næringsinnhold og bioaktive stoffer i potet

Tørrstoff- og stivelsesinnholdet er høyere i økologisk enn i konvensjonelt dyrka poteter. Høyt næringsinnhold i jorda fører til rask vekst av potetknollene på bekostning av tørrstoff og stivelsesinnholdet i konvensjonell dyrking. Det er ingen forskjeller på nivået på askorbinsyre, makro- og sporstoffer mellom dyrkingssystemene. I de fleste undersøkelser er nitratinnholdet høyere i konvensjonell enn i økologisk potet på grunn av høyere nitrogeninnhold i jorda i konvensjonell enn i økologisk produksjon

Næringsinnhold og bioaktive stoffer i frukt

De fleste undersøkelser viser at økologiske epler er fastere og har høyere innhold av tørrstoff, askorbinsyre, antioksydanter og sekundære plantemetabolitter med antioksidant aktivitet enn konvensjonell epler. Resultatene viser stor variasjon innen og mellom dyrkingssystemene.

Næringsinnhold og bioaktive stoffer i bær

Resultatene fra de fleste inkluderte studiene viste at økologiske bær har høyere sensorisk kvalitet og innhold av sekundære plantemetabolitter med antioksidant aktivitet og noen mineraler enn konvensjonell bær. I noen av studiene var det ikke effekt av dyrkingssystemene, mens andre fant høyere verdier i konvensjonell enn i økologisk bær.

Næringsinnhold og bioaktive stoffer i grønnsaker

For grønnsaker er resultatene variable og mindre klare. I noen studier hadde grønnsaker dyrket i økologiske produksjonssystem høyere innhold av noen næringsstoffer og sekundære plantemetabolitter med antioksidant aktivitet, mens in andre undersøkelser var det ikke noen virkning av dyrkingssystemene på analyserte næringsstoffer. Nitratinnholdet var lavere i noen og i andre studier høyere i økologisk enn i konvensjonelt dyrka grønnsaker. Derfor er det ikke mulig å trekke en klar konklusjon om virkningen av dyrkingssystemer på innholdet av næringsstoffer og nitrat i grønnsaker.

Miljøgifter

Det er svært lite opptak av de fleste organisk kjemiske miljøgifter fra jorda. Forskjeller i innholdet av miljøgifter i jord skyldes for det meste kilder som ikke er påvirket av økologisk eller konvensjonell praksis. På grunn av høgt humant inntak er korn og grønnsaker viktige kilder for tungmetaller i dietten. De data som foreligger gir ikke grunnlag å konkludere om forskjeller i nivået av metaller mellom økologisk og konvensjonelt dyrka matplanter.

Mykotoksiner

Kontaminering av korn med *Fusarium*-mykotoksiner er utbredt. Det er varierende resultatene fra sammenligning av økologisk og konvensjonell korn. De fleste studier fant ingen forskjeller i DON-innhold og flesteparten av resten finner lavere innhold i økologisk enn i konvensjonelt korn. De fleste undersøkelser viste lavere innhold av T-2 og HT-2 i økologisk enn i konvensjonelt dyrket korn. Økologiske dyrkere har bedre vekstskifte, pløyer mer og gjødsler svakere som gir tynnere plantebestand enn hos konvensjonelle dyrkere. DON-produserende sopper blir delvis bekjempet med sprøyting, mens det ikke finnes godkjente sprøytemidler mot sopper som danner T-2 og HT-2.

Fire studier viste høyere mykotoksin-innhold i økologiske enn i konvensjonelle epler, mens syv undersøkelser fant samme innhold. Forskjellene kan komme av bedre bekjempelse av soppsjukdommer i konvensjonelle frukthager, noe som reduserer mengden av mykotoksin-produserende sopper i eplene.

Såvare og settepoteter

Det er publisert få sammenlignende studier av økologiske og konvensjonelle såvarer og settepoteter, og det er ikke mulig å trekke noen konklusjoner om kvalitetsforskjeller. I noen undersøkelser ble det funnet mer frøoverførte sjukdommer i økologisk enn i konvensjonelt dyrka frø.

Nøkkelord

Økologisk vs. konvensjonell, plantehelse, planteproduksjon, kulturplanter, planteskadegjørere, næringsstoffer, miljøgifter, mykotoksiner, frøkvalitet, ugras

Contents

Background

The goal of the Norwegian government is that 15% of the agricultural production is organic in 2020 (St. Meld. 9, 2011-2012). However, knowledge on the impact of an increase in organic production in Norway is limited. If and how organic production practices may affect human health, animal health and welfare, plant health, the environment and sustainability is not clear.

In order to be able to give scientifically based information and advice on this issue to consumers and other target groups, the Norwegian Food Safety Authority (NFSA) requested a scientific evaluation of current research and other data on organic food and food production from The Norwegian Scientific Committee for Food (VKM). The scientific evaluation and the knowledge will also be used in connection with the NFSA's regulatory and international work on organic food production. The NFSA first prepared a draft request that was put out for public consultation. Remarks from the bodies that commented on the proposal clearly stated that there are limitations in the basic data for such an evaluation. NFSA therefore limited the scope and focus of the request somewhat. Sustainability aspects and environmental impact of organic and conventional agricultural practices are not addressed. In addition, organic aquaculture, which has only been practiced for a few years, is excluded from the request.

All foodstuffs on the market shall be safe and wholesome. Whereas all food produced and marketed shall comply with relevant legislation, food marketed as organic must in addition comply with regulations specific for organic production.

Organic food production is defined in Council Regulation (EC) No 834/2007 of 28 June 2007 on organic production and labelling of organic products as "The use of the production method compliant with the rules established in this Regulation, at all stages of production, preparation and distribution". The regulation on organic food production is part of the EEA Agreement and covers inputs, crop production, livestock production, rules for processing, labeling, and inspection, and provides provisions for imports from third countries.

According to Council Regulation (EC) No 834/2007, organic production shall be based on the following principles (article 4):

(a) the appropriate design and management of biological processes based on ecological systems using natural resources which are internal to the system by methods that:

- i) use living organisms and mechanical production methods;
- ii) practice land-related crop cultivation and livestock production or practice aquaculture which complies with the principle of sustainable exploitation of fisheries;
- iii) exclude the use of GMOs and products produced from or by GMOs with the exception of veterinary medicinal products;
- iv) are based on risk assessment, and the use of precautionary and preventive measures, when appropriate;

(b) the restriction of the use of external inputs. Where external inputs are required or the appropriate management practices and methods referred to in paragraph (a) do not exist, these shall be limited to:

- i) inputs from organic production;
- ii) natural or naturally-derived substances;
- iii) low solubility mineral fertilisers;

(c) the strict limitation of the use of chemically synthesised inputs to exceptional cases these being:

i) where the appropriate management practices do not exist; and
ii) the external inputs referred to in paragraph (b) are not available on the market; or
iii) where the use of external inputs referred to in paragraph (b) contributes to unacceptable environmental impacts;

(d) the adaptation, where necessary, and within the framework of this Regulation, of the rules of organic production taking account of sanitary status, regional differences in climate and local conditions, stages of development and specific husbandry practices.

Terms of reference

The Norwegian Food Safety Authority (NFSA) requests the Norwegian Scientific Committee for Food Safety (VKM) to evaluate current scientific knowledge of organic production and organically produced food based on existing national and international research results and other documentation. The NFSA wants the evaluation to focus primarily on Norwegian production.

NFSA has found it appropriate to divide this comprehensive evaluation of organic production and organic food into five parts:

1. Plant health – plant production
2. Animal health – animal welfare and feed
3. Human health – nutrition and contaminants
4. Human health – hygiene and pathogens
5. Human health – pesticide residues

NFSA would like VKM to compare the effects of organic versus conventional production based on the evaluations that are done in the five areas above. If lack of data prevents such a comparison, this should also be reported.

Part I. Plant health – plant production
NFSA requests VKM to compare plant properties and plant health using organic production systems versus conventional production systems. We are particularly interested in products that also are produced in Norway: Seeds, potatoes including seed potatoes, grass, grains, fruits (apples, plums, cherries), berries (strawberries, red raspberries, black currant) and vegetables (carrot, brassica, onion, tomatoes, cucumber, salad).

<u>NFSA requests VKM to identify and/or assess:</u>

- differences between levels of various nutrients (e.g. vitamins, antioxidants, bioactive substances, minerals, protein, fat and carbohydrates), plant pests, contaminants (heavy metals, other environmental toxins), and mycotoxins found in organically produced raw materials and conventionally produced raw materials.
- differences in quality (purity, germination capacity, health etc.) between organic and conventional seed potatoes and seeds.

Assessment

1 Introduction

The Norwegian Scientific Committee for Food Safety (Vitenskapskomiteen for mattrygghet, VKM) has at the request of the Norwegian Food Safety Authority (Mattilsynet, NFSA) compared organic and conventional food and food production in relation to possible impact on plant health, animal health and welfare and human health. The assessment is based on published peer reviewed scientific literature and assessment reports by international and national scientific bodies.

The following aspects of organic food production were not addressed in the assessment as they were not part of the request; sustainability aspects and environmental impacts of organic and conventional agricultural practices, and furthermore: aquaculture, because organic aquaculture has only been practiced for a few years.

At the request of the Norwegian Food Safety Authority the assessment was divided into five parts addressing:

I) Plant health and plant production (assessed by Panel on Plant Health)
II) Animal health and animal welfare (assessed by Panel on Animal Health and Welfare)
III) Humane health - nutrition and contaminants (assessed by Panel on Nutrition, Dietetic Products, Novel Food and Allergy)
IV) Human health – hygiene and pathogens (assessed by Panel on Biological Hazards)
V) Pesticide residues (assessed by Panel on Plant Protection Products)

The present report focuses solely on plant health and plant production. VKM appointed a working group consisting of VKM members and external experts to prepare a draft opinion. The opinion was approved by VKMs Panel on Plant Health. The Scientific Steering Committee of VKM approved the final opinion, i.e. this document.

2 Literature review process

This chapter describes the review process conducted for retrieving the scientific documentation available for this opinion, including the literature search strategy, search terms, and criteria for literature selection. The review process was initiated by the preparation of a protocol which pre-specified the method to be used for the conduct of the review.

2.1 Search strategy

Experts in various research fields, a project coordinator, and a librarian participated in planning the search strategy. In order to identify all relevant published literature we searched by using the databases' controlled vocabulary (subject headings) as well as text word searching.

The following databases were searched: EMBASE, MEDLINE, ISI Web of Science, CAB Abstracts and Agris. Each database was searched individually. Searches in Medline, Embase and ISI Web of Science were conducted by Wenche Jacobsen, head librarian at the Norwegian Institute of Public Health (NIPH). Searches in CAB Abstracts and Agris were conducted by Bente M. Fønhus and Sidsel Kolflaath, specialist librarians at the Norwegian

University for Life Sciences (UMB). The searches were performed between June and September 2013.

The literature search was performed without any exclusion criteria. Exclusion of literature was performed after the search, according to pre-specified criteria. These can be seen in sections 2.3 and 2.4.

The inclusion criteria of the literature search were:

Crop:	Various plants, fruits, berries and vegetables
Comparison:	Organic vs. conventional production

Outcome:

1. Plant health
2. Content of nutrients
3. Content of environmental contaminants
4. Content of mycotoxins
5. Quality in seed potato
7. Quality in seed

Type of study:	All types of studies
Publication language:	All languages included
Publication year:	All years

The topics were complex, and we therefore decided to separate the searches according to outcome. The search terms and the search strategies are listed in appendixes no. 1A-F.

2.2 Study type

We identified three main study types for inclusion in the current opinion:

2.2.1 Field trials

Comparisons between samples originating from organic and conventional agricultural methods on adjacent parcels of land (fields).

Strengths: adjacent land minimises variability between samples, greater control over agricultural inputs.

Weaknesses: expensive to conduct, time-consuming.

2.2.2 Farm surveys

Comparisons of samples originating from organic and conventional farms which may be matched for selected variables.

Strengths: makes use of existing agricultural infrastructure, large samples available.

Weaknesses: multiple farm sites introduce variability.

2.2.3 Basket surveys

Comparisons of samples of organically and conventionally produced food as available to the consumer from retail outlets.

Strengths: inexpensive to conduct, quick.

Weaknesses: no means of determining details of farming methods, little comparability between samples.

2.3 Publication selection

The titles and abstracts of all papers identified in the search process were assessed for relevance by one reviewer. Review papers/reports, meta analyses, grey literature such as dissertations, conference proceedings (including peer-reviewed abstracts) and reports, and also relevant in-press articles, were reported separately in our report but were not presented in the tables. The full texts of each potentially relevant article was retrieved and assessed for inclusion by one reviewer. Articles were excluded if they:

1. were published before 1991
2. did not address one or several of the following subjects: a) plant pests; b) seed quality; c) seed potato quality; d) content of nutrient and other substances; e) content of heavy metals or contaminants; f) content of mycotoxins
3. for subjects a, c-f): did not address one or several of the following crops: potato, seed potato, wheat, barley, oats, grasses, rye, apple, plum, cherry, strawberry, raspberry, blackcurrant, carrot, cabbage, swede, onion, tomato, cucumber, lettuce/salad.
4. for subject b): did not address seeds of one or several of the following crops: wheat, barley, oats, grasses, rye, oil seed rape, cabbage, faba beans, pea, carrot, onion
5. did not address raw plant material but processed plant material (processed food, drinks, etc.)
6. did not present a direct comparison between organic/ecological/biodynamic and conventional/integrated production systems

In addition, for literature presented as results, articles were excluded also if they:

7. were not peer-reviewed
8. were authentication studies describing techniques to identify production systems
9. were on studies performed in non-temperate climate
10. were on studies performed in third countries not approved by the Norwegian government for import of organic food.

2.4 Study quality

For the articles presented as results, study quality was categorised based on concordance with five fundamental factors which were defined as essential to answer the terms of reference. Study quality was grouped into two categories: satisfactory quality and unsatisfactory quality.

Satisfactory quality publications provided the following:

1. a clear definition, in the Introduction or Methods section of the paper, of the organic/ecological/biodynamic production methods of the crop product analysed
2. specification of the crop
3. a statement of which parameters were assessed: which plant pests were assessed for presence, or of which seed or seed potato quality parameters were assessed, or of which nutrient(s) and other substance(s) or mycotoxin(s) or heavy metal(s) or contaminant(s) were assessed for content, or of which plant production factors were assessed for influence on the product.
4. the use of satisfactory laboratory analytical methods to test for the listed parameters, and a satisfactory description of these methods.
5. a statement of the statistical methods used for data analyses.

Unsatisfactory quality publications were those that do not specify all of the above.

2.5 Data extraction

Se Appendix 2 A-F

3 Results/Review of the literature

3.1 Search results

The search strategy identified 16352 studies which were screened by subject headings, titles and abstracts by the 8 experts. Studies which did not meet the inclusion criteria (page 20) were excluded. The experts also performed additional searches and identified 125 additional relevant studies. Altogether 1007 studies were retrieved in full text and evaluated by the experts. Of these were about 460 included in this review.

This study selection process is described Appendix 1A – F.

Details about the studies included in this review are described in Appendix 2 A – F.

In the following chapters the results of the evaluation of studies (based on the data in Appendix 1 and 2) are presented in detail.

3.2 Comparison of plant health

3.2.1 Arthropods (Insects, spiders and mites)

This part summarizes the effects of organic vs. conventional farming primarily on insect pests and their natural enemies (predators and parasitoids). It has been suggested that organic farming may also benefit crop pollination, and as insect pollinators represent an additional ecosystem service in agricultural landscapes, studies of such pollinators have also been reviewed. In section 3.2.1.1 results from our survey of original studies are presented. The surveyed publications are listed and presented in more detail in table 6 in Appendix 2A 6.2). In section 3.2.1.2 we summarize conclusions made by published review papers on the subject, identified in our systematic literature survey.

Seventy-three publications fulfilled the criteria and were reviewed and are commented upon in the following section. Some of these publications dealt with several insect groups and different biological indicators, therefore the total number of studies adds up to 143.

3.2.1.1 Results of the present survey of original research studies

<u>Overview</u>

Rather few studies compare the pest population or crop damage by insect pests in organic vs. conventional farming systems. The reason for this bias is probably that the conventional farmer has different insecticides at hand which are banned in organic farming, so the result is in many ways given in advance. Only 15 per cent of the reviewed studies include crop damage and/or crop pests, and when the crop pest is specified to insect group it is often aphids.

The role of predators and parasitoids has always been in focus as natural biological control agents in the plant protection strategies within organic farming. General predators as ground beetles, rove beetles and spiders have been targets for numerous studies. Studies on the effect of specialists as aphid-specific predators or aphid parasitoids have also been frequent.

In the 143 studies the response of the organisms to organic farming relative to conventional farming has been divided into three different categories: an increase, no effect or a decrease. In most cases the effect on species richness and abundance has been investigated. Summarizing the responses of all biological indicators investigated, 57 per cent of the studies indicated an increase in species richness and abundance in organic compared with conventional fields or farms, 26 per cent indicated no effects and 17 per cent of the studies concluded with a decrease.

Crop pests

Twenty-three studies compared crop pests in organic vs. conventional farming (table 1). Eight of these concentrated on aphid pests. Ten of the 23 studies showed an increase in crop damage or abundance of species in organic relative to conventional farming management. Seven studies showed no effects of the farming system, while six studies had a decrease in crop damage or in the abundance of the insect species in organic relative to conventional farming.

Table 1. Response of crop pests (insects) to organic farming relative to conventional farming: + increase; 0 no effect; - decrease. The table summarizes the results of selected studies that compare crop damage and/or abundance in organic vs. conventional farming.

Organism	Effect	Crop damage		Abundance		Total no. of studies
		No. of studies	References	No. of studies	References	
Aphids (Aphididae)	+	0		2	(Macfadyen et al., 2009), (Koss et al., 2005)	2
	0	0		0		0
	-	0		6	(Gosme et al., 2012) (Krauss et al., 2011), (Garratt et al., 2010), (Roschewitz et al., 2005b), (Knight, 1994), (Moreby et al., 1994)	6
	SUM	0		8		8
Other insects	+	3	(Holb et al., 2012), (Hummel et al., 2002), (Rhainds et al., 2002)	5	(Veromann et al., 2009),(Koss et al., 2005), (Ngouajio and McGiffen, 2004), (Hummel et al., 2002), (Rhainds et al., 2002)	8
	0	3	(Rhainds et al., 2002), (Letourneau and Goldstein, 2001), (Drinkwater et al., 1995)	4	(Feber et al., 1997), (Moreby, 1996), (Drinkwater et al., 1995), (Knight, 1994)	7
	-	0		0		0
	SUM	6		9		15
TOTAL		6		17		23

Arthropods in general

Fifteen publications have dealt with arthropods in general (table 2), including a few relating to soil invertebrates without specifying the taxonomic groups, but all were restricted to crop pests, natural enemies or "indifferent" species in agricultural areas. Two studies showed negative effects of organic farming, while six gave no effects and seven showed a positive effect of organic farming on arthropods.

Table 2. Response of arthropods to organic farming relative to conventional farming: + increase; 0 no effect; - decrease. The table summarizes the results of selected studies that compare species richness and/or abundance in organic vs. conventional farming.

Effect	Species richness		Abundance		Total no. of studies
	No. of studies	References	No. of studies	References	
+	3	(Macfadyen et al., 2009), (Clough et al., 2007b), (Reddersen, 1997)	4	(Ponce et al., 2011), (Poveda et al., 2006), (Reddersen, 1997), (Moreby et al., 1994)	7
0	3	(Batary et al., 2012), (Diekotter et al., 2010), (Alvarez et al., 2001)	3	(Kragten et al., 2011), (Mikula et al., 2011), (Birkhofer et al., 2008a)	6
-	1	(Ponce et al., 2011)	1	(Moreby et al., 1994)	2
SUM	7		8		15

Natural enemies

General predators

Ground beetles (Carabidae), rove beetles (Staphylinidae), and spiders (Araneae) are numerous and important predators in all kind of arable crops. These predators feed on a large range of different pest species as preys, and they have often been shown to have a great impact in minimizing the pest population and crop damage. Sixty studies comparing the effect of organic vs. conventional farming have focused on these three groups of general predators (table 3). Some general conclusions can be drawn, although some cases point to opposing results between the different feeding groups of the beetles or spiders. In 52 per cent of the studies a positive response by organic farming on species richness or abundance were shown, while 32 per cent of the studies could not point to any effects of the farming systems. Only 16 per cent of the 60 studies demonstrated a negative effect of organic farming on these natural enemies. The effects on rove beetles varied; however, for this group only abundance has been studied. Twenty cases studying the effects on spider species richness or abundance were found, and 12 of these indicated a positive effect of organic farming. However, of these 12, only one study dealt with spider species richness while the rest focused on the abundance of spiders comparing organic and conventional fields or farms. Only one study showed a negative effect on spiders in organic vs. conventional farming.

Table 3. Response of ground beetles (Carabidae), rove beetles (Staphylinidae) and spiders (Araneae) to organic farming relative to conventional farming: + increase; 0 no effect; - decrease. The table summarizes the results of selected studies that compare species richness and/or abundance in organic vs. conventional farming.

Organism	Effect	Species richness		Abundance		Total no. of studies
		No. of studies	References	No. of studies	References	
Ground beetles	+	8	(Eyre et al., 2013), (Schroter and Irmler, 2013), (Batary et al., 2012), (Eyre et al., 2012), (Menalled et al., 2007), (Pfiffner and Luka, 2003), (Clark, 1999), (Pfiffner and Niggli, 1996)	9	(Eyre et al., 2013), (Schroter and Irmler, 2013), (Kragten et al., 2011), (Pfiffner and Luka, 2003),(O'Sullivan and Gormally, 2002), (Andersen and Eltun, 2000), (Sean Clark, 1999), (Pfiffner and Niggli, 1996), (Booij and Noorlander, 1992)	17
	0	5	(Ekroos et al., 2010), (Clough et al., 2007a), (Purtauf et al., 2005), (Weibull et al., 2003), (O'Sullivan and Gormally, 2002)	5	(Eyre and Leifert, 2011), (Diekotter et al., 2010), (Birkhofer et al., 2008a), (Purtauf et al., 2005), (Weibull and Ostman, 2003)	10
	-	3	(Eyre et al., 2013), (Diekotter et al., 2010), (Weibull et al., 2003)	3	(Eyre et al., 2013), (Ekroos et al., 2010), (Menalled et al., 2007)	6
	SUM	16		17		33
Rove beetles	+	0		2	(Clough et al., 2007c), (Pfiffner and Niggli, 1996)	2
	0	0		2	(Birkhofer et al., 2008a), (Weibull et al., 2003)	2
	-	0		3	(Eyre and Leifert, 2011), (Clough et al., 2007c), (Andersen and Eltun, 2000)	3
	SUM	0		7		7
Spiders	+	1	(Batary et al., 2012)	11	(Kragten et al., 2011), (Mikula et al., 2011),(Birkhofer et al., 2008b), (Birkhofer et al., 2008a), (Oberg, 2007), (Schmidt et al., 2005), (Pfiffner and Luka, 2003), (Miliczky et al.,	12

Organism	Effect	Species richness		Abundance		Total no. of studies
		No. of studies	References	No. of studies	References	
					2000), (Pfiffner and Niggli, 1996), (Moreby et al., 1994), (Booij and Noorlander, 1992)	
	0	5	(Diekotter et al., 2010) (Clough et al., 2007a), (Clough et al., 2005), (Schmidt et al., 2005), (Weibull et al., 2003)	2	(Mikula et al., 2011), (Clough et al., 2005)	7
	-	0		1	(Pfiffner and Luka, 2003)	1
	SUM	6		14		20
Total		22		38		60

Other predators and parasitoids

Aphids are important pests in arable crops, especially in cereals. Several researchers have investigated the effect of the aphid-specific predators and parasitoids comparing organic and conventional farming (table 4). Thirteen such studies were found studying parasitism/predation rate, species richness, or abundance. Seven studies showed a positive effect, four showed no effect, and two showed a negative effect of organic vs. conventional farming. A recent study (Lohaus et al., 2013) focused on aphid-primary parasitoid-hyperparasitoid food webs, and they concluded that agricultural intensification appears to foster the complexity of aphid-parasitoid food webs, thereby not supporting the general expectation on the importance of organic farming practices for species richness and food web complexity.

Only a few studies of natural enemies of agricultural pests, excluding aphids, were recorded (table 4). The effect on parasitism, predator consumption, species richness or abundance was studied in totally ten cases, and in all cases a positive response of organic vs. conventional farming on the predators or parasitoids was detected.

Table 4. Response of parasitoids and predators, additional to those presented in table 3, to organic farming relative to conventional farming: + increase; 0 no effect; - decrease. The table summarizes the results of selected studies that compare parasitism/predation rate, species richness and/or abundance in organic vs. conventional farming.

Organism	Effect	Parasitism/predation rate		Species richness		Abundance		Total no. of studies
		No. of studies	References	No. of studies	References	No. of studies	References	
Parasitoids and predators on aphids	+	2	(Gagic et al., 2012), (Knight et al., 1994)	0		5	(Moschini et al., 2012), (Krauss et al., 2011), (Koss et al., 2005), (Ostman et al., 2003), (Ostman et al., 2001)	7
	0	3	(Macfadyen et al., 2009), (Roschewitz et al., 2005b), (Schmidt et al., 2005)	1	(Macfadyen et al., 2009)	0		4
	-	0		0		2	(Garratt et al., 2010), (Moreby et al., 1994)	2
	SUM	5		1		7		13
Other parasitoids and predators	+	4	(Maalouly et al., 2013), (Birkhofer et al., 2011), (Veromann et al., 2009), (Knight, 1994)	3	(Mates et al., 2012), (Macfadyen et al., 2009), (Drinkwater et al., 1995)	3	(Eyre and Leifert, 2011), (Koss et al., 2005), (Booij and Noorlander, 1992)	10
	0	0		0		0		0
	-	0		0		0		0
	SUM	4		3		3		10
TOTAL		9		4		10		23

<u>Effects of organic vs. conventional fertilizers on crop pests and their natural enemies</u>

Additional information of the effect of farming systems can be found in nine studies only dealing with the effect of organic or conventional fertilisers on crop pests or their natural enemies (predators and parasitoids) living on plants supplied with the different fertilisers (table 5). Four studies showed positive effect, one study showed no effect, and four studies showed negative effect of organic fertilizers on parasitism or abundance. These results are divergent and give little support to the studies presented in the tables 1-4.

Table 5. Response of crop pest and natural enemies to the effect of organic vs. conventional fertilisers: + increase; 0 no effect; - decrease. The table summarizes the results of selected studies that compare parasitism and abundance due to organic or conventional fertilizers.

Effect	Parasitism		Predator abundance		Crop pest abundance		Total no. of studies
	No. of studies	References	No. of studies	References	No. of studies	References	
+	1	(Ponti et al., 2007)	2	(Banfield-Zanin et al., 2012), (Eyre et al., 2009)	1	(Staley et al., 2010)	4
	0		1	(Minarro et al., 2009)	0		1
-	0		2	(Garratt et al., 2010), (Eyre et al., 2009)	2	(Staley et al., 2010), (Alyokhin and Atlihan, 2005)	4
SUM	1		5		3		9

3.2.1.2 *Published literature reviews*

Seven reviews are surveyed. Even if the scope of these reviews differed (some include insects from all over the world, they cover different periods etc.), they are of interest since they all summarize the effect of organic vs. conventional farming on insect pests, their natural enemies or general biodiversity in agricultural landscapes. However, several of these reviews of published literature conclude that not only the farming systems but also a broader landscape perspective must be emphasized.

In an early meta-analysis of literature published before December 2002 where the effects of organic farming on species richness and abundance were analyzed, Bengtsson et al. (2005) concluded that insects usually showed an increased species richness in organic farming systems (Bengtsson et al., 2005). The abundance of predatory insects responded positively to organic farming, while non-predatory insects and pests did not. However, the analysis indicated that farmer practice only partly explained the variation in species richness and abundance. The surrounding landscape appeared to be more important than farming practice, a conclusion that was supported by other reviews (Tscharntke et al. 2005, Bianchi et al. 2006). Tscharntke et al. (2005) stated that understanding the negative and positive effects of agricultural use for the conservation of biodiversity, and its relation to ecosystem services, needs a landscape perspective.

In a review based on both literature and own research, Letourneau & Bothwell (2008) concluded that more studies are needed to assess the relationship between biodiversity and effective biological control. Although field studies showed that organic farms tended to conserve more biodiversity than conventional farms, including natural enemies of insect pests, they maintained that the effect of biodiversity had not been fully tested.

Prieto-BenÍtez & Méndez (2011) published a meta-analysis on the effects of land management on the abundance and richness of spiders, an important group of predators of pests in agroecosystems (Prieto-Benitez and Mendez, 2011). They concluded that conventional farming affected spider abundance, and that disturbances like insecticides are minimized in organic farming which resulted in significantly higher abundance of spiders. In another meta-analysis (Garratt et al., 2011) both the effects of farming systems and fertilizers on pests and natural enemies were reviewed. The organic farming favoured pests indicating that conventional pest control strategies available to conventional farmers are effective in reducing pest populations. The analysis suggested a positive effect of organic farming on natural enemy performance and abundance. Reasons for this might include the absence of chemical insecticides on organic farms. Effects of fertilizer types were divergent. There was no significant effect of the different fertilizer on pest responses, but the analysis showed a significant positive effect of organic fertilizer on natural enemy responses. Garratt et al. (2011) concluded that large-scale features of organic agriculture, such as landscape heterogeneity, could be beneficial to natural enemies (Garratt et al., 2011).

In a review, Crowder et al. (2010) showed that organic farming promoted evenness (the relative abundance of species) and natural pest control (Crowder et al., 2010). In an investigation of predators and pathogens in potato fields, they found that the evenness of natural enemies drastically differed between organic and conventional potato fields. Higher evenness in organic fields reflected relative equitable distributions of natural enemies, whereas conventional fields were relatively uneven because they were numerically dominated by one natural enemy taxon.

3.2.1.3 Conclusion

Due to the relatively few published studies it is difficult to draw a general conclusion on the effect of organic farming vs. conventional farming on crop pests (table 1). Investigations of such effects on the pests' predators and parasitoids are more numerous (e.g. table 3), and for these groups and for biodiversity in general there is a tendency towards a positive effect of organic farming on species richness and abundance (table 3 and 4). Such a conclusion is also supported by other reviews (mentioned above), although some of them emphasize that the heterogeneity of the landscape surrounding the agricultural fields and farms are essential. An additional positive effect of organic farming is the increase in pollinating insects.

More data are needed especially on single pest species in the major crops. Higher damage or higher pest populations are expected to be found in organic compared to conventional farming. Further studies will probably trigger more effort to develop new plant protection strategies as effective substitutes for chemical pesticides.

Further studies on natural enemies should focus not only on general predators and parasitoids, but to a larger extent include natural enemies specializing on single pest species. One may wonder why studies on e.g. ground beetles and spiders are so numerous in this respect. Is it because they are easy to catch in pitfall traps, and that their taxonomy is relatively well known?

3.2.2 Pollinating insects

Insect pollinators represent an additional ecosystem service in agricultural landscapes. It has been suggested that organic farming may benefit crop pollination; therefore studies of such pollinators have also been selected from the reviewed literature.

All of totally the 13 studies of pollinating insects in agricultural landscapes investigating pollination success, species richness or abundance, showed a positive response of organic vs. conventional farming (table 6). No negative effect was proved. A possible reason for this increased number of species and activity in organic fields are often attributed to an increased element of herbs, mostly categorized as weeds in organically farmed agricultural fields. Also, higher heterogeneity of landscapes and absence of pesticides in organic farming are likely reasons for the difference.

Table 6. Response of pollinating insects (Aphidae etc.) to organic farming relative to conventional farming: + increase; 0 no effect; - decrease. The table summarizes the results of selected studies that compare pollination success, species richness and/or abundance in organic vs. conventional farming.

Effect	Pollination success		Species richness		Abundance		Total no. of studies
	No. of studies	References	No. of studies	References	No. of studies	References	
+	3	(Andersson et al., 2012), (Power et al., 2012), (Gabriel and Tscharntke, 2007)	6	(Krauss et al., 2011), (Holzschuh et al., 2010), (Holzschuh et al., 2008), (Rundlof et al., 2008), (Clough et al., 2007a), (Holzschuh et al., 2007)	4	(Krauss et al., 2011), (Power and Stout, 2011), (Holzschuh et al., 2008), (Rundlof et al., 2008)	13
0	0		0		0		0
-	0		0		0		0
SUM	3		6		4		13

3.2.3 Nematodes

There is a very restricted volume of information available on nematodes, and since 1991 only a few papers were published reporting results which compare nematode abundance in organic and conventional production. Most studies report on the abundance of nematode trophic groups and indices of nematode diversity, while few publications give detailed information on abundance values of plant-parasitic nematodes.

With regard to trophic groups, three out of seven studies found bacterial feeding nematodes to be more abundant in organic production compared to conventional (Berkelmans et al., 2003), (Birkhofer et al., 2008a), (Tsiafouli et al., 2006). Two studies found plant feeders to be more abundant in organic fields (Birkhofer et al., 2008a), (Neher 1999), while one study found plant nematodes to be more abundant in conventional production (Briar et al., 2007). The abundance of the group of plant feeders and omnivores has also been reported to be comparable between conventional and organic systems (Ferris et al., 1996) There is one report on omnivores and predators being more abundant under organic management (Okada et al., 2009).

In some studies, differences between organic and conventional management with regard to species abundance of plant parasitic nematodes were registered.

In a four years study Briar *et al.* (2007) followed the nematode population dynamics during the transition from conventional to organic management (Briar et al., 2007). The conventional system had a corn-soybean rotation, while the organic system had a rotation comprised of corn-soybean-oats/hay (red clover and timothy). Initially the root lesion nematode *Pratylenchus crenatus* increased in both systems, but after four years it reached higher densities in the conventional system. The decline in the organic system was suspected to be due to a suppressive effect of timothy.

Berkelmans et al. 2003 presented results from a study of conventional management with a rotation of tomato-safflower-corn-wheat/beans with winter fallow, low-input management with a tomato-safflower-corn-purple vetch mixed with oats (winter cover crop), and organic management with tomato-safflower-corn-purple vetch mixed with oats (winter cover crop) (Berkelmans et al., 2003). The main contributive factors to difference between management types were the abundance of the root lesion nematodes (*Pratylenchus*) and the stunt nematode (*Tylenchorhynchus*). *Pratylenchus thornei* became more dominant with years, but it was suppressed in the organic and the low input management. Species in *Tylenchorhynchus*, which became more prominent in organic and low input farming systems, have wide host ranges on grasses and legumes used in the organic and the low-input management.

There appears to be no clear pattern emerging with regard to prevalence of feeding groups of nematodes in organic and conventional farming systems. This may depend on differences in time and space with regard to the drivers of nematode population build-up. As pointed out by Berkelmans *et al.* (2003) the crop plants may be more important for the nematode community than management system as such (Berkelmans et al., 2003).

Nematode damage occurs in organic farming systems. In Germany (Hallmann et al., 2007) reported that nematode problems may appear 5-10 years after conversion to organic management. The fundamental question is: Does nematode damage arise from organic management *per se*? In the literature there is currently not possible to find a clear answer to this question. The published information on nematodes in organic vs. conventional farming is much restricted, and do not often penetrate down to species level, and indeed not at all to a level of damage analysis.

Berkelmans *et al.(*2003) in their study of conventional, low-input and organic management of a tomato-safflower-corn rotation reported that the genus *Tylenchorhynchus* was favoured in organic and low-input management (Berkelmans et al., 2003). In a study of organic vineyards, Coll *et al*. (2012) reported that organic plots 7 and 11 years after conversion had higher densities of obligate plant feeders (*Paratylenchus* and *Tylenchorhynchus*) compared to conventional plots (Coll et al., 2012). Organic plots also had significantly more *Pratylenchus* and *Helicotylenchus* than conventional. There was a suspicion that the grass cover could have allowed plant feeders to reach high densities in organic plots.

Hallmann *et al.* (2007) identified 50 species of plant feeding nematodes from organic farming systems in Germany, and they mentioned that elements in organic farming that could promote the build-up of plant feeding nematodes include longer rotations, higher cropping frequency of legumes for nitrogen supply and short periods of fallow (Hallmann et al., 2007).

In view of the growing awareness and concern among growers of the potential nematode problems in organic farming (Jordbruksverket 2013), there is a need for more studies to better map the drivers for population build-up of nematode species and damage in conventional and organic farming systems.

Organic farming systems offer a higher challenge with regard to weed control due to the exclusion of herbicide treatments. Many species of weeds like allow for the maintenance and multiplication of plant parasitic nematodes.

The root-lesion nematode *Pratylenchus penetrans* in reported to increase in density on *Cirsium arvense* , *Chenopodium album* , *Elymus repens* and *Polygonum persicaria* (Bélair et al., 2007).

Host weed plants for the root-knot nematode *Meloidogyne hapla* in Norwegian fields are *Artemisia vulgaris* , *C.album*, *Senecio vulgaris* , *Taraxacum* spp. , *Capsella bursa-pastoris*, *P. persicaria* , *Lepidotecha suaveolens*, *Cirsium* spp., *Viola arvensis* and *Spergula arvensis*

(Magnusson et al., 2000). In addition to this *Stellaria media* and *Thlaspi arvense* also are reported as good hosts (Belair and Benoit, 1996).

The potato rot nematode, *Ditylenchus destructor,* also parasitizes weeds. Important species for keeping nematode infestations intact are *Stachys palustris* , *Sonchus arvensis* , *A. vulgaris*, *C. arvense* , *Tussilago farfara* and *E. repens* (Andersson, 1967).

The leaf nematode, *Aphelenchoides blasthophthorus,* which is important in Norwegian strawberry production, is favoured by many species of weeds. Examples of weeds that are hosts of this nematode are *Taraxacum* spp., *Plantago major*, *Ranunculus repens* , *Alchemilla* spp., *Rumex* spp., *Achillea millefolium* , *Rumex acetosa* , *Rumex acetocella* og *Ranunculus acris* (Anon. 2008). Hence, failure in weed control may allow these species, and probably others, to maintain their population densities and reach damaging levels.

3.2.3.1 *Conclusion nematodes*

There is no clear pattern emerging on the prevalence of nematode feeding groups in organic compared to conventional farming systems. The crop plants may be more important for the nematode community than management system as such. Since robust data on the effect of the management system on the abundance of species of plant parasitic nematodes and their damage is lacking, it is impossible to make statements on the role of organic farming in increasing or decreasing nematode damage.

3.2.4 Plant diseases

This part summarizes published information on differences in disease incidence between organic and integrated/conventional plant products. Plant diseases are caused by viruses, bacteria and fungi. The chapter mainly deals with plant diseases caused by fungi, since few bacterial and viral diseases of plants have been subject to comparative studies. Twenty-eight publications were included in the evaluation. For the major diseases on potato, cereals, apple and strawberry there are sufficient data available to reach conclusions. Only few studies have been published on diseases of vegetables and minor fruit and berry, and for these cultures it has not been possible to conclude on differences in disease incidence between the cultivation systems. The fungal diseases are most numerous and of greatest economic importance. In Norway there are no approved chemical control of plant pathogenic viruses and bacteria, and the plant protection strategies to prevent losses by viruses and bacteria are largely similar in organic and conventional production. Certified pathogen-free propagation material for planting is an important control strategy for viruses and bacteria. Fungi and pseudofungi (Oomycetes) may be controlled by fungicides in integrated and conventional agriculture, while in organic production only few chemical pesticides are available.

3.2.4.1 *Cereal diseases*

Cereals are susceptible to soil-borne pathogens such as the take all fungus (*Gaeumannomyces graminis*) and the root rot fungus (*Cochliobolus sativus* syn. *Bipolaris sorokiniana*). The eyespot pathogen (*Oculimacula* spp.) and the causal agent of sharp eyespot *Rhizoctonia cerealis* are dispersed by water splash during rain. Leaf and head pathogens such as barley scald (*Rhynchosporium secalis*), net blotch (*Pyrenophora teres*), glume blotch of wheat (*Phaerosphaeria nodorum*) and tan spot of wheat (*Pyrenophora tritici-repentis*) are disseminated by infected seed and water splash. The air-borne leaf pathogens powdery mildew (*Blumeria graminis*), yellow rust (*Puccinia striiformis*) and leaf blotch (*Mycosphaerella graminicola*) cause epidemics which develop rapidly over large areas. The snow mould fungus (*Microdochium nivale*) and the mycotoxin-producing *Fusarium* spp., causing head blight are seed transmitted and water-splash disseminated in the field by spores. *Fusarium* spp. may also cause brown foot rot and root rot of cereals.

Soil borne pathogens

In Poland Baturo (2007) recorded root rot symptoms caused by *Fusarium* spp. and *Cochliobolus sativus* in spring barley at the development stages “beginning of tillering” and “dough maturity”(Baturo, 2007). At both stages the disease indexes for organic cultivation were higher than those of integrated and conventional cultivation. Łukanowski (2005) in Poland found lower disease index of brown foot in conventional (11.3) than organic (15.9) and integrated (15.2) wheat (Lukanowski, 2005). Based on a farm survey of organic and conventional cereals in Denmark Knudsen et al. (1999) concluded that there were only small, but non-significant differences in microbial suppressiveness to the brown foot rot fungus (*Fusarium culmorum*) (Knudsen et al., 1999). In three years of field trials in Finland Hannukkala and Tapio (1990) found higher foot rot incidence in organic (54%) than in conventional (40%) barley the first year, the second year there was no difference and the third year the incidence on conventional (68%) was higher than on organic (47%) barley (Hannukkala and Tapio, 1990). Cropping systems had no effect on root rot in winter wheat. Stem base infection by the root rot fungus *C. sativus* was more severe on organic barley then on conventional barley all three years. During the first year take all was more severe on organic (36%) than conventional cereals (16%), while there was no difference during the next two years (Hannukkala and Tapio, 1990).

Table 7. Incidence of cereal foot and root rot (*Fusarium* spp. and *Cochliobolus sativus*) in organic farming relative to conventional farming: + increase, 0 no effect, - decrease. The table summarizes the results of selected studies that compare organic and conventional farming.

Effect	No of studies	References
+	2	(Baturo, 2007, Lukanowski, 2005)
0	2	(Knudsen et al., 1999), (Hannukkala and Tapio, 1990)
-	0	

Water splash disseminated pathogens

In the Czech Republic Matusinsky et al. (2008) reported that eyespot incidence was higher in conventional than in organic cereals, while there were only small differences in sharp eyespot incidences (Matusinsky et al., 2008). In field trials in the United Kingdom barley scald was more severe on organic (776% of conventional) than on integrated (356% of conventional) and conventional barley (Cooper et al., 2007). Net blotch was least severe in integrated barley (6% of conventional), while organic had most net blotch (111% of conventional) barley (Cooper et al. 2007). Based on Principal Component Analysis of data from field trials in Sweden L-Baeckström et al. (2006) found more severe glume blotch on conventional than on organic winter wheat, while tan spot incidence was higher on organic then on conventional winter wheat (L-Baeckstrom et al., 2006). They reported that *Fusarium* spp. were most common on conventional wheat in one year, while there was no difference between the cultivation systems in two years. Eltun (1996a) in Norway reported that glume blotch incidence was higher in organic (36%) than in conventional winter wheat (8%). Also, he reported that glume blotch was more severe in organic than in conventional spring wheat. Based on field trials in Sweden and Denmark Kristensen and Ericson (2008) concluded that foliar diseases seem to have less negative effect in organic than in conventional cereals, provided that pesticides are not applied (Kristensen and Ericson, 2008). During field trials in the Czech Republic snow mold incidence was higher in conventional than in organic winter wheat (Matusinsky et al., 2008). Lemanczyk (2012) in Poland reported that sharp eyespot mainly caused by *Rhizoctonia cerealis* was more severe in organic and conventional, than in integrated winter wheat (Lemanczyk, 2012).

Table 8. Incidence of foliage diseases of cereals (*Rhynchosporium secalis, Phaeosphaeria nodorum, Pyrenophora teres, P. tritici-repentis*) in organic farming relative to conventional farming: + increase, 0 no effect, - decrease. The table summarizes the results of selected studies that compare organic and conventional farming.

Effect	No of studies	References
+	3	(Cooper et al., 2007), (Eltun, 1996a), (L-Baeckstrom et al., 2006) *P. tritici-repentis*
0	0	
-	2	(Kristensen and Ericson, 2008), (L-Baeckstrom et al., 2006) *P. nodorum*

Bernhoft et al. (2010) sampled grain from organic farms and conventional neighboring farms in Norway. They found small but significantly higher percentage *Fusarium* spp. infected grain in conventional than in organic cereals (Bernhoft et al., 2010). For barley the mean percentages were: conventional (85%) and organic (81%), for oats: conventional (86%) and organic (81%) and for wheat: conventional (75%) and organic (64%). Based on field trials in winter wheat in France, Champeil et al. (2004) were unable to rank *Fusarium* spp. in conventional and organic systems, because neither was consistently more contaminated than the other (Champeil et al., 2004). Birzele et al. (2002) in Germany found higher incidence of *Fusarium* ear blight in conventional than organic winter wheat. During three years of field trials in Finland Hannukkala and Tapio (1990) found lower incidence of *Fusarium* spp. in organic (74%) than in conventional (97%) winter wheat in one year and no difference for 2 years (Hannukkala and Tapio, 1990). From field trials in Sweden and Denmark Kristensen and Ericson (2008) concluded that the foliar diseases barley scald, net blotch and leaf rust of barley have less negative effect in organic than in conventional cereals provided that pesticides are not applied (Kristensen and Ericson, 2008).

Table 9. Incidence of *Fusarium* head blight of cereals (*Fusarium* spp.) in organic farming relative to conventional farming: + increase, 0 no effect, - decrease. The table summarizes the results of selected studies that compare organic and conventional farming.

Effect	No of studies	References
+	0	
0	2	(Champeil et al., 2004), (Hannukkala and Tapio, 1990)
-	2	(Bernhoft et al., 2010), (Birzele et al., 2002)

Air-borne pathogens

Based on a farm survey in France Gosme et al. (2012) reported that leaf blotch was more severe in conventional than in organic wheat, while powdery mildew varied in severity between organic and conventional cultivation systems (Gosme et al., 2012). In United Kingdom Cooper et al (2007) found higher powdery mildew incidence in conventional than in integrated (70% of conventional) and organic (38% of conventional) barley (Cooper et al., 2007) Koch (1991) in Germany found less powdery mildew in biodynamic than in conventional wheat (Koch, 1991). In Norway Eltun (1996) reported on more severe powdery mildew on organic (22%) than on integrated (3%) and conventional (1%) winter wheat. Also, in spring wheat the powdery mildew incidence was higher in organic (18%) than in conventional wheat (2%) (Eltun, 1996a). In barley and oats there were only low powdery mildew incidence and no difference between cultivation systems (Eltun, 1996a). Hannukkala and Tapio (1990) in Finland found more powdery mildew on conventional than on organic winter wheat in three years of field trials (Hannukkala and Tapio, 1990). They reported on higher yellow rust incidence in conventional than in organic winter wheat in one year, while there was no difference during 2 of the 3 years field trial. Results from a farm survey in France showed that leaf blotch was more severe in conventional than in organic wheat (Gosme et al., 2012).

Table10. Incidence of cereal powdery mildew (*Blumeria graminis*) in organic farming relative to conventional farming: + increase, 0 no effect, - decrease. The table summarizes the results of selected studies that compare organic and conventional farming.

Effect	No of studies	References
+	1	(Eltun, 1996a) Spring wheat, winter wheat
0	1	(Eltun, 1996a) Barley, oats
-	3	(Cooper et al., 2007), (Koch, 1991),(Hannukkala and Tapio, 1990)

Reviews on cereal diseases under different cultivation systems

Van Bruggen (1995) reviewed studies of cereal diseases mostly performed before 1990. Snow mould and the airborne fungi causing yellow rust and powdery mildew were less severe in organic than in conventional cultivation. Increased disease severities in conventional fields were often associated with higher nitrogen fertilization and use of straw-shortener resulting in denser canopy. Other foliar diseases such as leaf rust of wheat and barley, leaf blotch and glume blotch of wheat and net blotch and scald of barley were similar in different cultivation systems. The latter group of diseases were sometimes more severe under organic or integrated cultivation. Van Bruggen (1995) also cited the results of the 100 year long Broadbalk experiments in United Kingdom. Eyespot, brown foot rot (*Fusarium* spp.) and sharp eyespot were more severe in plots well fertilized with farmyard manure or mineral fertilizer. Little difference was observed between plots that received manure and those that received mineral fertilizer.

Conclusion cereal diseases

There are different results from studies on soil borne diseases in organic and conventional cultivation. Some studies report on higher incidence of root rot and common root rot in organic cereals, while others find no difference. Some studies report on lower incidence of head blight caused by *Fusarium* spp. in organic then in conventional cereals, but there are studies that find no difference in *Fusarium* incidence between the cultivation systems. There is a report on higher incidence of powdery mildew in organic than in conventional cereals, but three reports conclude that there are lower powdery mildew incidence in organic cereals. For other leaf and head infection pathogens there are no consistent difference in disease incidence between the cultivation systems.

3.2.4.2 *Potato diseases*

Late blight (*Phytophthora infestans*) is the major potato disease in temperate climate. During humid periods the pathogen develops rapidly on the foliage, and it infects the tubers in the field. Infected tubers rot during storage. Breeding for resistance has provided some varieties with moderate to high resistance to the disease. The effect of resistance may be reduced over time by the pathogens ability to change. Common scab (*Streptomyces scabies*), caused by a soil-borne bacterium, is the most important tuber disease in the field. The fungus *Rhizoctonia solani* causes sprout rot which reduce germination, and the pathogen also develops black scurf on the tuber surfaces. The gangrene fungus (*Boeremia foveata*) and the dry core fungus (*Fusarium caeruleum*) cause storage rots.

Runno-Paurson (2013) in Estonia did field trials with potato late blight (Runno-Paurson et al., 2013). They concluded that most cultivars are too susceptible to late blight for organic cultivation without chemical control in North-East European climate. Zarzynska and Szutkowska (2013) in Poland compared late blight development in four potato varieties which varied in late blight resistance, from moderately resistant to susceptible (Zarzynska and Szutkowska, 2013). They concluded that resistance level was more important for development of late blight in the field than the difference between organic and conventional cultivation. There was no difference in rate of disease development between organic and conventional potato. Zarzynska and Szutkowska (2013) reported that reduced development of potato foliage in organic compared to conventional potato affected the microclimate and led to later appearance of the first symptoms and slower late blight development in organic potato (Zarzynska and Szutkowska, 2013). Palmer et al. (2013) in UK reported on similar results, and they concluded that increased severity of late blight in organic crop protection systems only occurred when conventional fertilization regimes were applied (Palmer et al., 2013). Varis et al. (1996) in Finland reported on more severe late blight epidemics on susceptible then on resistant cultivars of organic potato, while in integrated/conventional cultivation with fungicide application there were only minor differences between the cultivars. Storage losses, mainly caused by late blight tuber infections, were higher in organic potato (10.1%) than in integrated (3.7%) and conventional potato (3.3%) (Varis et al., 1996).

Table 11. Incidence of late blight (*Phytophthora infestans*) in organic farming relative to conventional farming: + increase, 0 no effect, - decrease. The table summarizes the results of selected studies that compare organic and conventional farming.

Effect	No of studies	References
+	2	(Runno-Paurson et al., 2013), (Varis et al., 1996)
0	0	
-	2	(Zarzynska and Szutkowska, 2013), (Palmer et al., 2013)

Based on three years of field trials Lenc et al. (2012) in Poland found no difference in common scab incidence between the organic and conventional cultivation systems, while Lenc (2006) reported on lower common scab incidence (35.1%) in organic than in integrated (40.9%) potato cultivation during three years of field trials (Lenc et al., 2012, Lenc, 2006).

Lenc et al. (2012) reported that sprout rot was more severe in organic (26.2%) than in integrated (17.6%) potato (Lenc et al., 2012). They found lower black scurf incidence in organic (14.3%) than in integrated (22.5%) potato. In a previous study Lenc (2006) concluded that sprout rot was more severe in integrated (40.9%) than in organic (35.1%) potato, while he could find no difference in black scurf incidence between the cultivation systems (Lenc, 2006). Based on a three year farm survey Keiser et al. (2012) in Switzerland concluded that there was no difference in black scurf incidence between organic, integrated and potato cultivation (Keiser et al., 2012).

Keiser et al. (2012) reported that the storage disease dry core caused important economic losses in all cultivation systems, but the disease was most severe in organic potato with reduced quality and lower price for 29 % of the fields (Keiser et al., 2012). On integrated and conventional farms 3 % of the fields produced potato which led to price reduction during the 3 year period. Lenc et al. (2012) concluded following three year field and storage trials that the incidence of dry rot was low both in organic (0.9%) and in integrated (2.8%) potato (Lenc et al., 2012). Povolny (1995) in Sweden did field and storage trials with 3 potato cultivars, and he reported that the gangrene rot occurrence was lowest in organic potato in January, but in April there was no difference in gangrene rot between organic and conventional potato. The dry rot varied with cultivars, and there was no clear difference between the cultivation systems (Povolny, 1995).

Review on potato diseases

In a review of plant diseases in high input compared with reduced input cultivation van Bruggen (1995) reported that late blight of potato was significantly more severe in organic compared to integrated and conventional cultivation. Most of her data were from studies performed before 1990.

Conclusion potato diseases

Late blight is so severe on susceptible potato cultivars that only resistant cultivars can be grown organically in climate with annual late blight epidemics. No potato cultivar is completely resistant. Two studies found more severe late blight on organic potato and two studies reported on more severe late blight in conventional potato. The limited number of comparative studies on other potato diseases does not provide sufficient data to conclude that their incidence in organic cultivation is different from their incidence in integrated and conventional potato cultivation.

3.2.4.3 *Apple diseases*

In temperate climate apple scab (*Venturia inaequalis*) is the most important apple disease. The fungus overwinters in dead leaves on the orchard floor and on tree branches. Sexual spores produced on dead leaves infect the new foliage in early spring and asexual spores produced on the new leaves initiate epidemic infections on foliage and shoots throughout the growing season. During the late summer fungal infections cause scab on apple fruit, which reduce the quality. Apple powdery mildew (*Podosphaera leucotricha*) is a major disease in continental climate. Other fungi such as the canker fungus *Botryosphaeria obtusa* and the white rot fungus *Schizophyllum commune* (syn. *S. alneum*) damage apple trees by infection on stems and branches. Apple fruit is susceptible to storage diseases such as bull's eye rot (*Neofabrea alba* and *N. malicorticis*) and brown rot (*Monilina fructigena*), where the infections take place in the orchards and the rot develops during storage.

In Hungary Holb et al. (2012) determined fruit quality of scab- resistant and scab-susceptible apple cultivars in integrated and organic production systems during four years of field trials (Holb et al., 2012). Mean final scab incidence was higher in organic (0-23.2%) than in integrated (0-2.4%) cultivation, except for the resistant cultivars which had no fruit scab in either system. On susceptible cultivars the copper and sulphur fungicides used in the organic production provided less effective disease control than the fungicides used in integrated control, and the scab incidence was 10-20 times higher on organic than in integrated cultivation. By sampling apple leaves after harvest but before leaf fall in organic and integrated, commercial orchards in the Netherlands Holb et al. (2005 a) found higher incidence of apple scab on leaves from organic orchards than on leaves from integrated orchards (Holb et al., 2005a). When they studied winter survival of the apple scab fungus at bud break in the spring, they found a lower number of viable conidia in buds from integrated trees than in buds from organic trees. Holb et al. (2005 b) studied the progress of apple scab epidemics in the humid climate of the Netherlands and in the continental climate in Hungary (Holb et al., 2005b). Disease progress of the apple scab was recorded in experimental orchards with integrated and organic-sprayed and organic-unsprayed cultivation. The apple scab disease progress started in June in organic plots and for integrated plots at the end of July in Hungary and in the beginning of August in The Netherlands. The disease progress was most rapid in organic-unsprayed and decreased in order organic-sprayed and integrated. In Sweden Jönsson et al. (2010) reported on more apple scab on leaves from organic trees than on leaves from integrated trees. Apples from organic orchards had more apple scab than apples from integrated orchards (Jönssson et al., 2010).

Table 12. Incidence of apple scab (*Venturia inaequalis*) in organic farming relative to conventional farming: + increase, 0 no effect, - decrease. The table summarizes the results of selected studies that compare organic and conventional farming.

Effect	No of studies	References
+	3	(Holb et al., 2005a), (Holb et al., 2005b), (Jönssson et al., 2010)
0	0	
-	0	

Jönsson et al. (2010) found bull's eye rot to be more severe on organic apples of the cultivar 'Aroma' than on integrated apples of the same cultivar. On the cultivar 'Karin Schneider' the disease incidence was lower, and there was no difference between organic and integrated apples (Jonssson et al., 2010). Brown rot was not a major problem in the studies of Jönsson et al. (2010). In Hungary Holb (2008) reported that conidial density of the brown rot fungus increased after the appearance of the first infected fruit in early July in organic and in early August in integrated orchards (Holb, 2008). Final brown rot incidence reached 4.3-6.6% in integrated and 19.8-24.5% in organic orchards. Epidemics of brown rot started two to four weeks earlier in organic than in integrated orchards in Hungary (Holb and Scherm, 2007).

In Bulgaria Borovinova et al. (2012) studied the canker fungus *B. obtusa* and the white rot fungus *S. commune* in an experimental orchard with organic, integrated and conventional cultivation. They reported that *B. obtusa* damage on trunk and branches was more severe in organic than in integrated and conventional cultivation (Borovinova et al., 2012). Borovinova et al. (2012) considered *S. commune* a secondary invader following *B. obtusa* infection.

The etiology of apple replant disease is unknown, which makes it difficult to study the effect of cultivation systems. Manici et al. (2003) in Italy reported that soil from organic orchard had higher level of total cultivable fungi than soil from conventional orchards, while they did not find any difference in cultivable bacteria in soil from the two cultivation systems. Apple growth in soil samples from organic orchards was more rapid than in soil from conventional orchards (Manici et al., 2003).

<u>Conclusion apple diseases</u>

Apple scab is the most important apple disease in temperate climate. Both in organic and integrated/ conventional cultivation control of this disease require the attention of the growers from bud break to harvest. The disease is more severe in organic production, since less efficient control methods are available. Planting resistant varieties is the most reliable method for apple scab control in organic orchards. Also, other apple diseases are serious in organic cultivation, but there are too few comparative studies to conclude that there are any differences in disease incidence between the cultivation systems.

3.2.4.4 *Strawberry diseases*

The grey mould fungus (*Botrytis cinerea*) is the most serious pathogen on strawberry because it rots the berries in the field and after harvest. Spores of the fungus are present in the air throughout the growing season, and during humid periods the disease rapidly destroys the strawberries. The wilt fungus (*Verticillium dahliae*) is one of several soil borne pathogens that kills plants in the field.

During two years Spornberger et al. (2011) in Austria studied the effect of organic and conventional fertilization and plant protection practices on the grey mould fungus and the wilt caused by *V. dahlia* (Spornberger et al., 2011) . In 2004 grey mould losses were lower in conventional (5%) than in organic (7.6-9.4%) strawberries. The percentage of marketable fruit was 79% for conventional and 72.1-73.7% for the two organic treatments. The grey mould incidence was very low in 2005 with 0.2% in conventional and 0.7-0.9 in organic strawberries. In Upstate New York, USA, Rhainds et al. (2002) tested the fungus *Trichoderma harzianum* in biocontrol of grey mould in organic and conventional strawberries. They reported on low levels of grey mould and found no effect of cultivation system on the grey mould incidence in strawberries (Rhainds et al., 2002).

During two years Spornberger et al. (2011) studied the effect of *V. dahliae* on strawberry fruit quality. Both years there were no differences in poor fruit quality caused by the wilt fungus between organic and conventional strawberries (Spornberger et al., 2011). Also, Njoroge et al. (2009) in USA did not find any difference in *Verticillium* wilt between organic and conventional strawberries. Crop rotation had no effect, but rotation with broccoli as a break crop reduced the disease level (Njoroge et al., 2009).

Jensen et al. (2013) in Denmark did a farm survey of the microbiota and possible toxins produced by fungi (mycotoxins) on healthy strawberries. About 700 strawberries were collected from each of four organic and four conventional growers. Bacteria were most numerous on strawberries, followed by yeasts and filamentous fungi. There was no difference between the microbiota on strawberries sprayed with fungicides and organic strawberries. Mycotoxins were not detected in strawberries from any of the eight growers (Jensen et al., 2013).

<u>Conclusion strawberry diseases</u>

Few comparative studies of strawberry diseases in organic and conventional cultivation have been published. Grey mould is a major challenge for both organic and conventional growers. With few effective control methods available the yield losses from grey mould are larger in organic than in conventional cultivation. For other strawberry diseases there are too few comparative studies to conclude that the cultivation system will influence the disease incidence.

3.2.4.5 *Other fruit and berries*

<u>Pear, plums and cherries</u>

No comparative studies of diseases on organic and conventional plums and cherries have been found.

Black currants and raspberry

No comparative studies of diseases on organic and conventional black currants and raspberries have been found.

3.2.4.6 *Vegetable diseases*

Several species of field vegetables, each with specific diseases, are cultivated in Norway. Some crops like lettuce, broccoli and cauliflowers are marketed directly from the field. Cabbage, carrots, onions and swedes are marketed at the time of harvest and throughout a several month long storage period. Diseases cause losses both during cultivation in the field and in storage. The number of studies comparing the effect of organic, integrated and conventional cultivation on disease incidence on field vegetables is very limited. The search did not identify any comparative studies on diseases of crucifers, cucumbers and lettuce. A few publications report on diseases of organic and conventional tomato grown in the field. As commercial tomatoes are produced in greenhouses in Norway, the results from field trials are not applicable. No studies comparing disease in organic and conventional greenhouse vegetables have been detected.

Carrot

The liquorice rot fungus (*Mycocentrospora acerina*) survives in plant debris and infects carrot foliage in the field. Spores produced on leaves may follow the product into storage. Because of its ability to grow and cause rot at the recommended storage temperature for carrots, the liquorice rot fungus is a serious carrot pathogen. For two years Louarn et al. (2012) in Denmark placed organic and conventional carrot in standard storage conditions for 6 months. In one of the storage season there was no difference in liquorice rot incidence between non-inoculated organic and conventional carrot. The next year non-inoculated organic carrot had more liquorice rot than non-inoculated conventional carrot. In both years carrots inoculated with *M. acerina* developed lesions more rapidly than non-inoculated carrot. After one month of storage inoculated organic carrot had bigger lesions than inoculated conventional carrot. There was no difference in liquorice rot incidence between inoculated carrots from the two cultivation systems after four month in storage (Louarn et al., 2012).

Carrots with cavity spot caused by *Pythium* spp. are not marketable. The pathogen penetrates the carrot surface in the field and causes cell breakdown and cavities. Dresbøll et al. (2008) in Denmark recorded cavity spot in field trials during four years. They found more cavity spot in conventional then in organic carrots one year and more cavity spots in organic than in conventional carrots the next year. During two of the four years the disease was absent. When they summarized the results over four years there was no difference in cavity spot prevalence between the cultivation systems (Dresbøll et al., 2008).

Bender and Ingver (2012) did field trials in Estonia and concluded that cultivation system had no effect on marketable yield of carrots (Bender and Ingver, 2012).

Onion

Onion has a sparse root system without root hairs and depends on arbuscular mycorrhizal fungi (AMF) in onion roots for water and nutrient uptake. Galván et al. (2009) reported from field trials in The Netherlands that the yield of conventional onion was positively correlated with AMF colonization levels. They also found that organic and conventional farming systems had similar AMF diversity (Galván et al., 2009). A physiological disorder in onions is “watery scales” which makes the onion non marketable. Bacteria and fungi infect the watery outer scales and cause decay. Dresbøll et al. (2008) recorded watery scales in organic and conventional onion, and they found no difference in watery scales between onions from the two cultivation systems (Dresboll et al., 2008). Also, there was no difference in decay between the cultivation systems.

Conclusion field vegetables

The few comparative studies on carrot and onion diseases in different cultivation systems do not provide sufficient data to conclude that there are differences in disease incidence between organic and conventional field vegetables.

3.2.5 Weeds and their control in organic and conventional farming

3.2.5.1 *Introduction*

General

Weed management on agricultural land depends largely on crop rotation, soil cultivation and seed cleaning to keep weeds at a manageable level (Bond, 2002). The conversion to organic and low-input farming has brought about a re-evaluation of non-chemical weed management strategies that involve the whole cropping system. Probably not so focused, but it was the introduction of improved seed-cleaning machinery that probably made the greatest single contribution to reducing weed problems before the advent of herbicides (Bond, 2002).

Growing a succession of different crops prevented any weed species from becoming dominant. In addition, “cleaning crops” were included to reduce the potential weed population before growing poorly competitive crops known to favour weeds (Korsmo, 1954; Bond 2002).

For optimizing measures for non-chemical weed control, especially regarding perennial weeds, knowledge of weed biology is crucial for determining the best method, including the timing of operations. In the past few decades, numerous studies, many of which were performed in the Nordic countries, have helped to elucidate weak points in the lifecycles of perennials. One such study on weed biology and practical consequences is the discovery of innate dormancy in perennial sow-thistle (*Sonchus arvensis)* in late summer and autumn, causing this species to be more difficult to starve by soil cultivation in the growth season than, e.g., couch grass (*Elymus repens)* (Brandsæter et al., 2010). Another example is the findings of Thomsen et al. (2013) that shoots from the intact root system contributed considerably more to the total biomass produced by creeping thistle (*Cirsium arvense*) than did the root fragments in the upper soil layers, telling us that depth of soil tillage is crucial for the control of this species.

To successfully control weeds in organic farming, a variety of both preventive and direct measures must be included. Melander et al. (2005) stated that weed harrowing and interrow hoeing provide promising results, when they are part of a strategy that also involves cultural methods such as fertilizer placement, seed vigor, seed rate, and competitive varieties (Melander et al., 2005). Crop rotation is crucial for controlling most perennial weed species, crop rotation is crucial. To control dock species, e.g., (*Rumex longifolius* and closely related species) crop rotation is essential. For Central Europe, it is estimated that more than 80% of all herbicides used in conventional grassland farming are used to control various *Rumex* species (Zaller, 2004). The challenge of controlling these species in organic farming is formidable if a proper crop rotation is not included in a holistic cropping system.

Some studies have focused on understanding the growth conditions and factors that best explain a certain weed situation. For example, Rydberg and Milberg (2000) evaluated the relative importance of some farming practices like the actual or preceding crop, undersown ley, weed harrowing, weed hoeing, ploughing regime, compost, animal husbandry, biodynamic agriculture and the present weed species. Among other findings, they summarized that there was a tendency for weed species that dominate in conventional farming to be more nitrophilous than those species characteristic for organic farming (Rydberg and Milberg, 2000). Furthermore, Fried et al. (2008) in France found that the major variations in (weed) species composition between fields were associated with human management factors; (1) the current crop type and (2) the preceding crop type (Fried et al., 2008). Three main weed communities were identified according to sowing season: winter, spring and summer-sown crops. The third most important factor was associated with soil pH, and to a lesser degree, soil texture. Thus, weed
communities on basic clay soils differed significantly from those on acidic sandy soils. The influence of climate and geographical region was less pronounced and identified mainly through relationships with precipitation and longitude. Within certain crop types, the effect of other management practices became more prominent.

One aspect that distinguishes the control of weeds from the control of other types of harmful organisms is that the weed control measures are often closely related to other factors and objectives. For example, weed control and nutrient supply are often closely linked in organic production. One example is that the use of undersown cover crops in cereals may render mechanical weed control impossible if the cereal and the cover crop are sown at the same time. Another jeopardizing aspect is that cover vegetation growing in autumn will prevent stubble cultivation (Rasmussen et al., 2006), which is a commonly used non-chemical treatment against couch grass.

Some of the papers reviewed dealt with basic mechanisms trying to find explanatory variables behind potential differences between organic and conventional farming. For example Gallandt et al. (1998) suggested that organic amendments and green manure promote a potato crop to better be able to compete with weeds, and that these inputs should be considered as potentially important components of integrated weed management systems with minimal reliance on herbicides (Gallandt et al., 1998). Another example of more mechanistic studies is Fischer et al. (2011) and Navntoft et al. (2009) who compared mixed effects of landscape complexity and farming systems on weed seed removal (seed predation) (Fischer et al., 2011,Navntoft et al., 2009).

A couple of studies have focused on local and neighborhood effects of organic and conventional management including pests, weeds and diseases. Gosme et al. (2012) concluded that their results indicated that an increase in organic acreage in landscapes will not increase pest problems in the short term under the conditions of the study (low disease pressure) (Gosme et al., 2012).

In some cases there have been somewhat difficult to decide whether a study should be included or not because different use of terms related to organic farming, for example Nazarko et al. (2003) is using both ‘pesticide free production’, certified organic’ and ‘non-certified organic’ (Nazarko et al., 2003).

Crop rotation

The classification (Life form of weed plants) used in Table 13 is largely based on Korsmo (e.g. (Korsmo, 1954) and (Håkansson, 2003). This well-known classification system, based on the main groups of annual, biennial and perennial weeds, and sub-groups and their relationship to different crop groups, is highly relevant for describing which groups of weeds will probably increase in density if a certain group of crops (e.g. cereals) is frequently included in the rotation. For example, frequent cultivation of spring sown cereals may increase the density of perennial weed species with rhizomes tolerant to soil cultivation, such as couch grass (*E. repens*), as well as species with thickened roots, such as creeping thistle (*C. arvense*) and perennial sow-thistle (*S. arvensis*).

The matrix in Table 13 presents solutions for including grassland in the crop rotation to reduce problems with creeping thistle (*C. arvense*) and perennial sow-thistle (*S. arvensis*). For grassland, including annual crops will probably reduce the dock (*Rumex* spp.) problem.

Table 13. Relative potential of plants with different life forms to grow and reproduce as weeds in different kinds of crops in the absence of active control by chemical or mechanical means. Characteristics of plant groups as seen as entiretiesa (after Håkansson 2003, some modifications included).

Life form of weed plants		Annual crops			Perennial crops: mainly leys in crop rotations	
		Potato Sugar beet Vegetables	Cereals, oilseed crops		Young leys	Older leys
			Spring-sown	Autumn - sown		
1. Annuals	1.1 Summer annuals	III	III	I-II	I	-
	1.2 Winter annual	III	II	III	II	I
2. Biennials**		-	-	-	-	-
3. Perennials	3.1 Stationary perennials[1]	I	-	-	II	III
	3.2 Creeping perennials					
	3.2.1 Stolons[2]	I-II	-	-	II	III
	3.2.2 Rhizomes					
	3.2.2.1 Sensitive*[3]	I	-	-	I	III
	3.2.2.2 Tolerant*[4]	III	III	II-III	III	II-III
	3.2.3 Thickened roots[5]	III	III	II-III	II-III	I-II

*Sensitive or tolerant to soil cultivation. [a] Grading: III= maximal; II=somewhat reduced; I=limited;
’–‘=minimal. Note: grading values are comparable only horizontally. They do not inform on quantitative abundance or importance.**Scentless mayweed (*Tripleurospermum inodorum) (balderbrå) is classified as winter annual in Swedish literature, most often as a biennial in Norwegian literature. Independent of group of life form, scentless mayweed will be graded ‘III’ in autumn sown cereals/oilseed crops.*

<u>Examples of weed species</u>: [1] Dandelion (*Taraxacum officinale* / løvetann) and docks (*Rumex longifolius* and closely related species / ‘høymole’); [2] creeping buttercup (*Ranunculus repens* / krypsoleie); [3] common nettle (*Urtica dioica* / stornesle) and yarrow (*Achillea millefolium* / ryllik); [4] couch grass (*Elymus repens* / kveke), colt’s-foot (*Tussilago farfara* / hestehov) and field horsetail (*Equisetum arvense* / åkersnelle); [5] creeping thistle (*Cirsium arvense* / åkertistel) and perennial sow-thistle (*Sonchus arvensis* / åkerdylle).

3.2.5.2 *Cereals*

A very high percentage of the papers reviewed dealt with cereal dominated rotations. The papers differ in weed assessments as (i) species composition, (ii) species density, (iii) species biomass, (iv) species soil seed bank (e.g. (Sjursen, 2001), (Haghighi et al., 2013) etc.). For example, for species composition different kind of assessments and specifications are included, e.g. species richness, species number, Shannon’s diversity index, Beta diversity, Simpson dom. index, Hill’s first order diversity and Alfa/Beta/Gamma diversity (see Appendix 2A (6.3), Table 7 for data extraction weeds).

Heterogeneous field conditions are ubiquitous throughout agricultural systems and have given rise to the practice of site-specific management, in an effort to increase sustainability and/or homogenize growing conditions and thereby increase crop yields. The spatial pattern of weeds in conventional systems is widely accepted to be aggregated, but there has been no scientific studies regarding the spatial pattern of weed distribution in organic systems. Pollnac et al. (2008) found that weed cover was aggregated in both conventional and organic systems, but the patterns of aggregation were different for the two systems (Pollnac et al., 2008). Conventional no-tillage systems showed a patch/gap pattern, while organic systems showed multiple scales of patchiness with few gaps. These results suggest that the processes causing aggregation in the two systems may be different, and that site-specific management may be applicable to organic systems as well as to conventional spring wheat systems.

Weed species diversity

Weed species diversity (weed species richness) in the vegetation, seed rain and soil seed bank were higher in organic than in conventional fields (Roschewitz et al., 2005a). Higher weed species diversity in organic fields is found in numerous papers (Armengot et al., 2012); (Armengot et al., 2013); (Duer and Feledyn-Szewczyk, 2001a),(Duer and Feledyn-Szewczyk, 2001b),(Edesi et al., 2012), (Feledyn-Szewczyk and Duer, 2006a); (Feledyn-Szewczyk and Duer, 2006b); (Feledyn-Szewczyk and Duer, 2006c); (Glemnitz et al., 2006), (Gruber et al., 2000); (Hiltbrunner et al., 2008); (Hyvonen et al., 2003); (Romero et al., 2008); (Roschewitz et al., 2005a); (Rydberg and Milberg, 2000) (Table 15). Exceptions, however, with small or no differences between organic and conventional fields are also found e.g., (Graziani et al., 2012). Agha and Palutt (2006) found that changes in weed density and species composition of weeds occurred only after approximately 5 years (Agha and Pallutt, 2006). Dorner et al. (2004), who evaluated the general comparisons between conventional versus organic, found that higher weed diversity can be observed in fields where neither chemical nor mechanical weed control is done, and in which no stubble breaking is performed (Dorner et al., 2004). Furthermore, they concluded that on land that has been farmed organically for 15 years and on which mechanical weed control is done (e.g. weed harrowing), the number of weed species is low. These results are in contrast to those of Agha & Pallutt (2006), who found that weed harrowing did not affect weed species richness, whereas the use of herbicides did (Agha and Pallutt, 2006).

Although there are discrepancies between the various studies, the vast majority conclude that organic farming results in significantly increased species richness. Among the studies mentioned above, many are from Nordic countries, e.g. those of Hyvönen and Salonen (2005) in Finland (Hyvonen and Salonen, 2005), and there are no reasons to believe that the situation is different in Norway. Some of the studies raise the question whether organic farming can restore the species composition of arable weed communities back to their level at the onset of modern cropping measures in the 1960s (e.g. (Hyvonen, 2007)), and increased species richness is from that point of view a positive development. On the other hand, some species, e.g., marsh woundwort (*Stachys palustris* / åkersvinerot), which was more widespread before herbicides were available, increase their species richness and will be a recurring challenge for farmers.

Weed density and biomass

Summer annual and biennial weed species
More or less all weed species (Table 14) follow the same developmental pattern, higher densities and higher weed biomass e.g. (Salonen et al., 2013) are unanimously found on organic farms than on conventional farms.

One general problem regarding the evaluation of the included studies is, however, that (potential) weed management between sowing and harvesting the cereals is poorly or not described at all (e.g. (Albrecht, 2005); (Eyre et al., 2011)). If no direct management such as weed harrowing or hoeing is performed after sowing, it is not surprising that weed density and weed biomass are usually high. In many of the involved studies (e.g. (Albrecht, 2005); (Davis et al., 2005); (Feledyn-Szewczyk, 2012); (Feledyn-Szewczyk and Duer, 2006b), (Feledyn-Szewczyk and Duer, 2007), (Hyvonen and Salonen, 2005)), the organic cereals are undersown with white clover or other legumes. This makes mechanical weed control impossible if the cereal and the cover crop are sown at the same time. Undersowing at the same time as pre-emergence weed harrowing, prevents the use of post-emergence weed harrowing. While some previous studies have shown competitive effects of undersown white clover, reducing the number of weeds (Hiltbrunner et al., 2008), studies in Norway generally show very poor effects of undersown clover on weed number and biomass (Sjursen et al., 2012, Stenerud et al., submitted 2014). However, results vary between studies, and the weed suppression effect has been attributed to growth characteristics of specific clover species ((Den Hollander et al., 2007), (Hiltbrunner et al., 2008)), soil fertility (Hiltbrunner et al., 2007; Ross et al., 2001), weed flora and regional climate (Ross *et al.,* 2001). Rasmussen *et al.* (2006) found that the main effect of catch crops on weed biomass is linked to the weed control measure used and not the catch or cover crop itself (Rasmussen et al., 2006) .

Most of the reviewed studies show considerable differences both in weed number and biomass between conventional and organic farms, e.g. as shown by the Finnish surveys ((Salonen et al., 2001b); (Salonen et al., 2005); (Salonen et al., 2011)). There is no doubt that weed density and biomass on organic farms exceed the economic threshold, and that there is a need for improved weed control.

In many studies no mechanical treatments, e.g. weed harrowing, have been used (e.g. (Duer and Feledyn-Szewczyk, 2001a); (Feledyn-Szewczyk, 2012); (Feledyn-Szewczyk and Duer, 2006a); (Feledyn-Szewczyk and Duer, 2006b); (Feledyn-Szewczyk and Duer, 2006c)). In the Finnish surveys mentioned above, very few of the farmers practiced weed harrowing (Salonen et al., 2001b); (Salonen et al., 2005); (Salonen et al., 2011).

Hyvönen and Salonen (2005) found that the increase on ‘low input’ (compared to conventional) farms in weed biomass was much higher for annual weeds than for perennial weeds. In rye, the biomass of perennial weeds was more or less equal for the two cropping systems (Hyvönen and Salonen, 2005).

But, and as already mentioned, it is important to underline that no direct weed control measures were carried out on many, probably most, of the farms reviewed here. From this follows the question of whether the farmers have available tools for improving the control of annual weeds.

In the study of Jose-Maria & Sans (2011), the reported high seedling densities reflect the lack of appropriate weed management among organic farmers, the majority of whom did not carry out any mechanical weed control during the cropping period (10 out of 15, Jose-Maria and Sans, 2011). Weed harrowing with long-flex spring tines had only a moderately negative effect on both seedbank species richness and size (Table 16). This supports the idea that mechanical weed control is less effective than herbicides, particularly if fields are only harrowed once (Ulber et al., 2009). Therefore, in their study, they conclude that weed harrowing was not a sufficient measure per se for controlling weediness in organic fields, at least with the frequency of current use. Weed harrowing however shows better efficiency if the field is harrowed twice, combining both pre-emergence and post-emergence weed harrowing e.g. (Brandsæter et al., 2012). Although Brandsæter et al. (2012) did not find support for any synergistic effects between pre and post-emergence harrowing, the effect was additive and the combination gave better weed control efficiency compared to only one-time harrowing.

A recently published study (Stenerud et al., submitted 2014) showed that pre-emergence weed harrowing on average reduced the weed density by 32% and weed biomass by 49%, compared to pre+post-emergence weed harrowing, which reduced density by 59% and biomass by 67%. This is in line with several studies concluding that pre- and post-emergence weed harrowing improves the weed control efficiency in cereals compared to pre-emergence weed harrowing alone (Rasmussen and Rasmussen, 2000, Lundkvist, 2009, Brandsæter et al., 2012).

Weed assessments of the many studies without weed harrowing, referred to above and in Table 14, would have been significantly lower if pre- and post-emergence had been included. Furthermore, from a more holistic point of view, weed harrowing, as well as interrow hoeing, provide promising results when they are part of a strategy that also involves other measures such as fertilizer placement, seed vigor, seed rate, and competitive varieties (Melander et al., 2005).

Regarding competition from weeds, Armengot et al. (2013) concluded that use of herbicides, as well as weed harrowing, avoided yield decrease. In their study they found an average yield decrease of 23% on organic compared to conventional fields, and explained the decrease as probably being due to lower fertilizer rates on the organic farms (Armengot et al., 2013). As shown in Table 14, the organic cereal yields generally vary between 60 and 90 % of conventional yields. On average for all cereal species, organic yields were 28% lower (72% of conventional yields).

Without going into detail, Mason and Spaner (2006) and Mason et al (2007) hypothesize that crop cultivars developed before the advent of modern, high-input agriculture may be better suited to lower soil nutrient levels and elevated weed competition than the more modern ones (Mason and Spaner, 2006; Mason et al., 2007b).
Criteria for yield and weeds versus cereal traits are discussed and concluded. A competitive crop ideotype for organically grown spring wheat in northern growing regions of the Canadian Prairies should include taller plants, with fast early season growth, early maturity, and elevated fertile tiller number.

Perennial weed species

One might expect similarities in the weed flora of modern organic farming and pre-herbicide agriculture. Around 1920, farmers in Sweden ranked creeping thistle (*C. arvense*), couch grass (*E. repens*) and colt's foot (*T. farfara*), all perennials, as the most troublesome weeds (Adolfsson, 1996). However, none of these species were mentioned as being particularly common in the survey of Rydberg & Milberg (2000), suggesting that improved soil cultivation technology has reduced the weed pressure from perennial species since the 1920s (Rydberg and Milberg, 2000). However, the same authors claim that creeping thistle (*C. arvense*) and perennial sow-thistle (*S. arvensis)* seemed to be over-represented in organic farming.

Although the results and conclusions from different field experiments and surveys are not completely unambiguous, organic farmers generally have to overcome the problem of creeping perennial weed species (Table 14). This corresponds significantly with the relationship (Table 13) between this group of weed species and cereals (Håkansson, 2003).

Infestation by the perennial species couch grass (*E. repens*), creeping thistle (*C. arvense*) and perennial sow-thistle (*S. arvensis)* is of major concern e.g.((Salonen et al., 2001b),(Salonen et al., 2001a), (Salonen and Hyvonen, 2002); (Hyvonen and Salonen, 2005); (Agha and Pallutt, 2006)), but our knowledge regarding their biology as well as control methods has increased significantly during the two last decades; some examples below.

Numerous studies in conventional farming e.g.((Ekeberg et al., 1985),(Hakansson et al., 1998)) have shown the positive effects of ploughing on control of perennial weeds. There is general agreement that the effect increases with the depth of ploughing e.g. ((Børresen and Njøs, 1994), (Håkansson et al., 1998)). More recently, Kouwenhoven et al. (2002) showed that the main factor determining the minimum acceptable ploughing depth is the control of weeds, especially perennials (Kouwenhoven et al., 2002). Brandsæter et al. (2011) showed that perennial weed numbers and the total above-ground weed biomass were mostly 50% lower with deep ploughing than with shallow ploughing in spring (Brandsæter et al., 2011). The greatest effect of deep ploughing was seen in the control of creeping thistle (*C. arvense)*, which in some cases was reduced by more than 90% compared to shallow ploughing. The same research group later published new data, in which they summarized that the control efficiency of creeping thistle (*C. arvense)* and perennial sow-thistle (*S. arvensis)* was closely related to timing of ploughing (Brandsæter, submitted). Spring ploughing decreased the growth of both species significantly compared to autumn ploughing. For *E. repens,* however, timing of ploughing or bare fallow had no significant effect: the most important factor was whether bare fallow was carried out (best control) or not. Another influential factor is how farmers treat perennial weeds in the autumn, after harvesting. We know that stopping the weeds' assimilation and growth in autumn, by soil tillage or mowing, is crucial, especially for couch grass (*E. repens*) (Håkansson, 2003), which can be starved during the autumn. However, this also applies to weed species in which growth is reduced (Brandsæter *et al.,* 2012) due to different forms of dormancy (eco- or endo-dormancy). In cropping systems with limited access to livestock manure, a green manure ley is often included. In such a green manure crop, some weeds, e.g. creeping thistle (*C. arvense*), can be controlled with high efficiency by mowing frequently and at optimal developmental stages (Graglia et al., 2006).

Conclusion, cereals

Although there are discrepancies between the various studies, the vast majority concludes that organic farming results in a significantly increased (weed) species richness (Table 3: average + 67 %, (Armengot et al., 2012) not included). Almost all weed species (Table 2; Table 3) follow the same developmental pattern, higher densities and higher weed biomass are regularly found on organic farms than on conventional farms. It is important to underline that no direct weed control measures during the growth season were carried out on many of the farms reviewed here. There is no doubt that weed density and biomass on organic farms frequently exceed the economic threshold, and that there is a need for improved weed control for increasing crop yield. On average for all cereal species, organic yields were 28 % lower (Table 3) compared to conventional yields. Some studies, however, conclude concluded that proper use of weed harrowing, similar to the use of herbicides in conventional farming, avoid yield decrease caused by competition from annual weed species. A main obstacle for organic cereal production, at least on farms without livestock, is the creeping perennial weeds. Although problems with annual weeds should not be underestimated, the management of perennial weed species seems to be even more important for maintaining productivity.

To optimize measures for non-chemical control of perennial weeds, knowledge of weed biology is crucial for determining the best method and timing of the operations. To successfully control both annual and perennial weeds in organic farming, a variety of both preventive and direct measures must be included. There is a need for further studies on more holistic strategies including different cultural methods such as the use of organic fertilizers and placement, seed vigor, seed rate, competitive varieties. Furthermore, in both conventional and organic cropping systems, there is an immediate need to apply the latest technologies to improve the efficiency and economics of management while reducing the environmental impacts.

Table 14. Weed development divided into three groups: (i) decreasing, (ii) stable or (iii) increasing, for organic versus conventional farming or the weed development, compared to the initial population, after conversion to organic farming.

Weed classification	Sub group	Weed species	Weed development organic versus conventional[1]			Comments	References
			Decreas.	Stable	Increas.		
Summer annuals		*Centaurea cyanus* (kornblom)			x	Conv: More nitrophilous species	(Rydberg and Milberg, 2000)
		Vicia hirsute (tofrøvikke)			x		
					x	Cereals - under conversion[2]	(Agha and Pallutt, 2006)
		Veronica spp.		x		The same as in CONV	(Edesi et al., 2012)
		Almost all species			x	Cereal dominated rotation	(Edesi et al., 2012)
		Almost all species			x[3]	Mixed rotation	(Graziani et al., 2012)
		Fumaria officinalis (jordrøyk)			x	Spring cereals. CONV: *Galuim spurium* increase.	(Salonen et al., 2011)
Winter annuals		Almost all species			x	Cereal dominated rotation	(Edesi et al., 2012)
Biennials		*Tripleurospermum inodorum* (balderbrå)			x	Cereal dominated rotation	(Edesi et al., 2012)
					x	Winter wheat, conversion	(Krawczyk et al., 2010)
Perennial stationary							
Perennial creeping	Creeping roots	*Cirsium arvense* (åkertistel)			x	Spring cereals	(Salonen and Hyvonen, 2002)
				x		Spring cereals 1960-1990	(Hyvonen, 2007)
					x	Cereals -under conversion[1]	(Agha and Pallutt, 2006)
					x	Cereal dominated rotation	(Edesi et al., 2012)
					x	Mixed rotation.	(Eyre et al., 2011)
		Sonchus arvensis (åkerdylle)			x	Cereal dominated rotation	(Edesi et al., 2012)
					x	Spring cereals 1960-1990	(Hyvonen, 2007)
					x	Spring cereals	(Salonen and Hyvonen, 2002)

Weed classification	Sub group	Weed species	Weed development organic versus conventional[1]			Comments	References
			Decreas.	Stable	Increas.		
	Creeping rhizomes	*Elymus repens* (kveke)			x	Cereal dominated rotation	(Edesi et al., 2012)
					x	Spring cereals 1960-1990	(Hyvonen, 2007) (Salonen and Hyvonen, 2002)
			x			Mixed rotation (2yr. grass + 3yr. cereals)	(Hyvonen and Salonen, 2005)
		Tussilago farfara (Hestehov)			x	Cereal dominated rotation	(Edesi et al., 2012)
		Equisetum arvense (åkersnelle)		x		Cereal dominated rotation	(Edesi et al., 2012)
				x		Spring cereals 1960-1990	(Hyvonen, 2007)
	Tubers	*Stachys palustris* (åkersvinerot)		x		Spring cereals 1960-1990	(Hyvonen, 2007)
All weeds		7		x		Mixed rotation, organic crop protection.	(Eyre et al., 2011)
		15 species			x		
		31 species			x	Rotation-from 2 yrs. before to 6 yrs. after conversion	(Albrecht, 2005)
		3 species	x				
		40 species			x	Cereal dominated rotation	(Edesi et al., 2012)
		1 species	x				
		3 species		x			
Most dicotyledonous Weeds esp. *Tripleurospermum inodorum* (balderbrå)					x	Conv. Dominating weed: *Apera spica-venti* (åkerkvein) and *Viola spp.* Winter wheat, conversion	(Krawczyk et al., 2010)

[1]Either compared to the initial population after a period of organic farming, or compared to conventional plots/fields. [2]Changes in weed density and species composition of weeds occurred only after approx. 5 years. [3]Particularly *Portulaca oleracea* L., *Amaranthus retroflexus* L. and *Chenopodium album* L..

Table 15. Relative values for weed density, weed biomass and crop yield in organic ("Org"), conventional ("Conv") and non-treated fields ("Contr").

Weed density			Weed biomass			Species richness			Crop yield			Comments	References
Contr	Org	Conv	Contr	Org	Conv	Contr	Org	Conv	Contr	Org	Conv		
CEREAL DOMINATED ROTATIONS													
100	-54 (131)	-65 (100)	100	-52 (171)	-72 (100)					77[1]	100[1]	Winter wheat or barley. Spain.	(Armengot et al., 2013)
							70%[2] 62%[2]	36%[2] 53%[2]				Upper line: Spain Lower line: Germany	(Armengot et al., 2012)
										71	100[3]	Spring barley. Poland	(Duer and Feledyn-Szewczyk, 2001a)
							125[4]	100				Cereal dominated rotation. Lithuania	(Edesi et al., 2012)
	310	100					187	100				Mixed rotation, Finland	(Ekroos et al., 2010)
	216	100					140	100				Cereal, Finland	
				571[5]	100[5]					81[5]	100[5]	Spring wheat, Poland	(Feledyn-Szewczyk, 2012)
							115[6]	100[6]				Mixed rotation,	(Graziani et al., 2012)
							157[7]	100[7]		75[7]	100[7]	Cereal fields, Denmark	(Hald, 1999)
				700	100					80[8]	100[8]	Winter wheat in a mixed rotation, Switzerland	(Hiltbrunner et al., 2008)
				173	100					54[9]	100[9]	Rye, rotation 2 yrs. Grassland and 3 yrs. cereals.	(Hyvonen and Salonen, 2005)
				174	100					74[9]	100[9]	Oat-pea, rotation as above	
				184	100					63[9]	100[9]	Spring barley,	

Weed density			Weed biomass			Species richness			Crop yield			Comments	References
Contr	Org	Conv	Contr	Org	Conv	Contr	Org	Conv	Contr	Org	Conv		
												rotation as above	
							141	100				Winter cereals, Spain	(Jose-Maria and Sans, 2011)
				4000 (!)	100					64[10]	100	Mix wheat and spring cereals. Canada	(Kaut et al., 2008)
				1100 (!)	100					77[10]	100	Mix wheat varieties. Canada.	(Kaut et al., 2009)
										79	100	Oat, Russia	(Kovalev et al., 1995)
										74	100	Barley, Russia	
										67	100	Winter rye, Russia	
	158	100		189	100							Winter wheat, Poland	(Krawczyk et al., 2010)
										80	100	Winter wheat cultivars, Poland	(Kus et al., 2010)
				A[11]	B[11]					61	100	Spring wheat cultivars, Canada	(Mason et al., 2007b)
							300	100				Winter wheat, southern England	(Moreby and Sotherton, 1997)
	469 (345)	136[13] (100)		678 (416)	163[13] (100)		24[12] (150)	16[12] (100)				Spring cereals, Finland	(Salonen et al., 2001b)
							18 (180)	10 (100)				Field peas, Finland	(Salonen et al., 2005)
	519 (324)	160 (100)		775 (464)	167 (100)		21 (175)	12 (100)				Spring cereals, Finland	(Salonen et al., 2011)
	100-142			48-84						90	100	Oat, Estonia	(Tamm et al., 2009)

Weed density			**Weed biomass**			**Species richness**			**Crop yield**			**Comments**	**References**
Contr	Org	Conv	Contr	Org	Conv	Contr	Org	Conv	Contr	Org	Conv		
										66	100	Wheat, Estonia	
										64	100	Barley, Estonia	
POTATOS													
				210	100							Potatoes, Poland	(Rebarz et al., 2006)

[1] Aboveground dry weight. Cereal biomass was separated into spikes and straw. The total cereal biomass was highly correlated with the spike biomass. [2] ß-diversity. [3] ”Integrated” = 93%. [4] Mean of two organic treatments. [5] This study includes both conventional and integrated cropping practice. The used values are means of those two systems. [6] Small differences but index of diversity in CONV was on average higher than in ORG. [7] Species richness: only wild species. The difference is even bigger if spontaneous cultural species are included. Yield = total biomass. Of the total biomass, 12% is wild in Org and 2 % in Conv.[8] Huge yields, also in organic (5458 kg). [9] Not defined as organic, called ‘low input’ in the paper. No pesticides were used, fertililized with cattle manure. Generally low yields. [10] The value from research station, even lower yields (-70-80%) from certified organic farms. Extremely high weed biomasses in organic plots.[11] Significantly higher in organic farming. [12] Average species per field. [13] Unsprayed CONV: weed density 420 m^{-2} /weed biomass 605 kg ha^{-1}.
[14] Density: oat 100; barley 142; wheat 138. Biomass: oat 48; barley 80; wheat 8

3.2.5.3 *Vegetables and potatoes*

Vegetables

There are few comparative studies of conventional and integrated versus organic farming in vegetable production that include weed management and weed registrations. We only found four studies that presented such comparisons (Hillger et al., 2006; Karkanis et al., 2012; Raffaelli et al., 2011). A review of European research on physical and cultural methods in arable crops in general was published by (Melander et al., 2005).

There are a number of investigations on developing and optimizing the use of mechanical and thermal intrarow weed control methods, such as finger and torsion weeding, brush weeding, hoeing, harrowing, flaming and band steaming, see Melander et al. (2005) for a review until 2005. Today, even more innovative methods such as robot (non-chemical) weeding implements have been developed and are becoming commercially available. The status of this subject is reviewed by (Pérez-Ruiz et al., 2012). GPS based systems (positions of crop plants are coordinate specific) and automation of weed control are generally covered by a recently published scientific textbook (Young and Pierce, 2014). In both conventional and organic cropping systems, there is an immediate need to apply the latest technologies to improve the efficiency and economics of management while reducing the environmental impacts.

Weed control within crop rows is one of the main challenges in organic vegetable production, especially in sown crops (e.g. (Melander et al., 2005)). In many studies, the effectiveness of non-chemical methods has been measured in terms of the need for hand weeding (hrs ha^{-1}) (e.g. Hillger et al., 2006; Raffaelli et al., 2011).

Melander *et al*. (2005) reviewed physical and cultural methods of weed control developed by European research prior to 2005. Karkanis et al. (2012), who did their studies in Greece, concluded that the use of straw mulch is an option for weed management in organically grown leeks. In both experimental years the organic yields were 26% lower than in the best conventional treatment (Karkanis et al., 2012).

Weed control is also a challenge in organic tomato cultivation (Raffaelli et al., 2011). Organic production required a total labour input that averaged 50% more than the conventional strategy (Raffaelli et al., 2011). The conventional system generally had more effective weed control than the organic system, but both strategies controlled weeds effectively. In the USA, Hillger et al. (2006) found a labour requirement in conventional production of only 2 hours of hand weeding per hectare in processing tomatoes, and an average of 61 hrs/ha for fresh market tomatoes. In organic production, the corresponding figure was 280 hours/ha (Hillger et al., 2006).

Potatoes

Gallandt et al. (1998), Rebarz et al. (2006) and Barbas & Sawicka (2010) were among the very few papers reviewed that dealt with weed and weed control in potatoes ((Gallandt et al., 1998), (Rebarz et al., 2006), (Barbas and Sawicka, 2010)). The latter authors mentioned the importance of using cultivars with resistance to potato late blight (*Phytophthora infestans*) in organic farming, and that the competiveness of the crop versus the weeds is also crucial. The term “cleaning crops” was mentioned in the initial, general section as a method for reducing the potential weed population before growing poorly competitive crops known to favour weeds ((Korsmo, 1954, Bond 2002). Potatoes, including intensive harrowing and hoeing, is a frequently used example of a “cleaning up” crop. For example, Korsmo (1954) claimed that a two years period of intensive hoeing in potatoes is a good method for control of *Stachys palustris*. This species is known to be among the most persistent (the below ground vegetative organs are very persistent) creeping perennials in arable fields (Fykse, 1983).

Conclusions, vegetables and potatoes

There are few comparative studies of conventional and integrated versus organic farming in vegetable production that include weed management and weed registrations Weed control, in particular within crop rows, is one of the main challenges in organic vegetable production, especially in sown crops. It can be expensive and time consuming and severe crop yield losses may be incurred when weeds are not adequately controlled. There is a need for more knowledge on the combinations of adequate preventive and direct measures. There often is higher need for knowledge on proper use than for the development of new implements. Because the value of the crop in combination with the very high labour requirements in many vegetable crops, there are very clear needs for more innovative methods such as robot (non-chemical) weeding implements

3.2.5.4 *Fruits and berries*

Only a couple of real comparative studies ((Walsh et al., 2011), (Minarro, 2012)) of conventional or integrated versus organic farming in fruit production were found. One study on berry production, that includes weed management and weed registrations was found .

Strawberries
Organic production of strawberries is a challenge because of two main problems, (i) strawberry plants are generally poor competitors against weeds and (ii) there is a general experience that the weed problem increases with the age of the strawberry planting because non-chemical weed control is difficult in this crop.

Economic analysis indicated that a lack of reliable, effective measures for managing pests of strawberries without synthetic pesticides, especially weeds may severely constrain yield and profitability of organic strawberries in the northeastern United States (Rhainds et al., 2002).

Fruits/Orchards
Results clearly show that a proper pre-planting treatment, especially soil cultivation (black fallow), is important for controlling perennial weeds such as couch grass (*E. repens*) before establishing fruit trees.

Weed control in apple orchards, thereby reducing competition for water and nutrients, is basic to avoid a negative impact of weeds on tree performance (Minarro, 2012). One possibility for weed control within the tree rows is to cover the soil/surface with plastic mulch (Måge and Skogerbø 1992). Other possible mulch treatments are wood chips or straw, but this involves the need for re-mulching after some year(s). Some farmers use a living mulch, e.g. white clover, in the tree rows, but poor weed control and competition of clover versus the fruit trees is a challenge. Mechanical weed control within the rows, with special implements made for the use in orchards, is another possibility.

In the study of Miñarro (2012), herbicides and mulching hampered weed establishment more effectively than tillage (Miñarro, 2012). Tillage favoured therophytes (annual weeds), whereas herbicide use favoured hemicryptophytes (stationary perennial weeds), as a result of the different way these strategies keep the soil free of weeds and the impact they have on the soil. Mulching was associated with a decreased proportion of therophytes at the expense of hemicryptophytes. Cryptophytes (creeping perennial weeds) were not affected by the treatments.

Conclusions, fruits and berries

Only a couple of real comparative studies of conventional or integrated versus organic farming in fruit production were found. One study on berry production that included weed management and weed registrations was found. Although both special mechanical implements for weed control within the fruit rows, as well as plastic mulch, are available, organic farmers frequently mention proper weed control as an important challenge. Both for fruits and berries, weed control and soil fertility are closely related and there is a need for finding solutions that include both of them. In addition, the topography in Norway differs from most other countries, and it may therefore make it difficult to include methods developed under other circumstances.

Organic production of strawberries is a challenge because of two main problems, (i) strawberry plants are generally poor competitors against weeds and (ii) there is a general experience that the weed problem increases with the age of the strawberry planting because non-chemical weed control is difficult in this crop.

3.2.5.5 *Grassland*

No real comparative study of conventional or integrated versus organic farming on grasslands that includes weed management and weed registrations was found in the standard literature search.

Table 13 shows the importance of different life form of weed plants in younger and older leys. Although competition from annual weed species should not be ignored in the year of reseeding (renewing), there is no doubt that stationary perennials, for example dock species, are the most challenging species (Håkansson, 2003). The prevalence of dock species is a true bottleneck in the expansion of organic grassland and ley farming in Norway and elsewhere (Andersson, 2007). *Rumex obtusifolius* L. (broad-leaved dock) and *R. crispus* L. (curled dock), as well as other closely related dock species such as *R.longifolius* DC. (Northern dock), are among the most important perennial weeds in grassland areas throughout the world (Zaller, 2004). Zaller (2004) stated that *Rumex* infestation has increased on arable land during the last decades, while Galler (1989) estimated for Central Europe that more than 80% of all herbicides used in conventional grassland farming were used to control docks (Galler, 1989). There is also a particular need for more information on *R. longifolius*, as this is the species of greatest importance in Norway (Fykse, 1986) and yet it has been studied very little compared to *R. crispus* and *R. obtusifolius*.

Eyre et al. (2011) reviewed papers dealing with weeds in grassland, and he investigated how organic crop protection and organic fertilization affected *R. cripsus*, and concluded: (i) plus 100 per cent when using organic crop protection, (ii) but minus 50 per cent when using organic fertilization (Eyre et al., 2011). Hiltbrunner et al. found in their study (Hiltbrunner et al., 2008), in accordance to Table 1 (Håkansson, 2003), that the two stationary species, *Taraxacum officinale* and *R. obtusifolius*, increased with time and dominated the weed community in the maize which followed.

Kirchmann et al. (2007) found that crop yields were, on average, 50% less and weed biomass was greater (1-3 Mg dry matter ha-1) in the organic system than in the conventional system (Kirchmann et al., 2007).

Climate change during the last decades seems to be one of the explanations for a change in the weed species occurrence, especially in the coastal parts of western Norway. Soft rush (*Juncus effusus* L.) and compact rush (*J. conglomeratus* L.) are perennial weeds that commonly are found in both organic and conventional farms in these areas. In coastal parts of western Norway these species have mainly occurred in extensive grassland and pastures, but during the last decades they also have infested more intensively managed leys. The spread of rush causes a serious reduction in forage quality and covers former cultural landscapes. This may have an impact on meat and milk production, and reduce motivation for management of the agricultural landscape.

Conclusions, grassland

Although very few comparative studies were found it is possible to conclude that both weed species diversity and weed biomass are greater in organic farming compared to (intensive) conventional farming. Although annual weed species need attention when renewing grassland, stationary perennials, for example dock species, are the most challenging species. The future research needs can be categorized the following way: (i) Biological studies for uncovering “weak points” in the lifecycle of specific weed species. (ii) Long term field experiments to assess the role of management factors most often stated to be responsible for the specific weed species infestation and distribution (for dock species for example: N and K soil level including manure application, sward disturbance, harvest frequency/grazing management, soil cultivation when renewing, soil compaction).

3.3 Comparison of content of nutrients and bioactive substances

This part summarizes published information on differences in nutrient content between organic and integrated/conventional plant products. For the major cultures such as potato, cereals, apple, strawberry, tomato, cruciferous vegetables and carrots there are sufficient data published to reach sound conclusions. For the minor cultures few studies have been published, and it has not been possible to conclude on possible differences in nutrient content between the cultivation systems.

3.3.1 Nutrients and bioactive substances in potato

Potato starch is an important source of energy, and it has a function as dietary fiber. The potassium content of potato is higher than in most vegetables. Also, potato provides phosphorus, magnesium, calcium, iron, zinc and many trace elements. Potato is an important source of the vitamin C. Antioxidants like carotenoids and chlorogenic acid are also present in potato. Several authors have compared nutrient contents in potato produced under organic and conventional cultivation systems.

3.3.1.1 *Dry matter*

Most analyses of potato from field trials conclude that dry matter content is higher in organic potato than in potato grown under conventional or integrated cultivation. Based on field trials in Italy Lombardo et al. (2012) concluded that dry matter was higher in organic (22.2%) than in conventional (20.3%) potato (Lombardo et al., 2012) . After four years of field trials in Spain Herencia et al. (2011) reported on higher dry matter in organic potato in two of the four years (Herencia et al., 2011). In Ireland Gilsenan et al. (2010) found higher dry matter in raw potato from organic cultivation (21.8 %) than in conventional potato (20.1 %) (Gilsenan et al., 2010a). There was no difference in sugar content between the cultivation systems. Fjelkner-Modig et al. in Sweden reported on higher dry matter in organic (22.3%) than in integrated potato (21.3 %) (Fjelkner Modig et al., 2000). From the Norwegian Apelsvoll Cropping System Experiment Eltun (1996) concluded that dry matter content of organic potato (28.5%) was higher than for integrated (25.0%) and conventional (23.9%) potato (Eltun, 1996b). Also, Gilsenan et al. (2010) in Ireland, Hajšlová et al. (2005) in the Czech Republic, Roinilia et al. (2003) in Finland and Rembialkowska (1999) in Poland reported that dry matter content was higher in organic than in integrated and conventional potato (Gilsenan et al., 2010);(Hajslova et al., 2005); (Roinila et al., 2003) (Rembialkowska, 1999). Sawicka (2003) in Poland found lower dry matter content in organic (23.5%) than in integrated (24.5%) potato (Sawicka, 2003).

Table 16. Dry matter content of potato from organic farming relative to conventional farming: + increase, 0 no effect, - decrease. The table summarizes the results of selected studies that compare organic and conventional farming.

Effect	No of studies	References
+	8	(Lombardo et al., 2012), (Herencia et al., 2011), (Gilsenan et al., 2010), (Fjelkner Modig et al., 2000), (Eltun, 1996b), (Hajslova et al., 2005), (Roinila et al., 2003), (Rembialkowska, 1999)
0	0	
-	1	(Sawicka, 2003)

3.3.1.2 *Starch*

Most of the studies report higher starch content in organic than in integrated and conventional potato. In field trials in Poland, Flis et al. (2012) found higher starch content in potato from one organic (16.2%) and one conventional (15.4%) location (Flis et al., 2012). The second organic had 15.1% and the second conventional had 14.7% starch. Roinila et al. (2003) in Finland found higher starch content in organic than in conventional potato in two of three years of field trials (Roinila et al., 2003). Also, Lombardo et al. (2012), and Varis et al. (1996) in Finland reported on higher starch content in organic than in conventional potato (Lombardo et al., 2012);(Varis et al., 1996). Jørgensen et al. (2012) in Denmark and Maggio et al. (2008) in Italy did not find any difference in starch content between the cultivation systems (Jørgensen et al., 2012);(Maggio et al., 2008). Sawicka (2003) in Poland found lower starch content in organic (15.04%) than in integrated (15.54%) potato (Sawicka, 2003).

Table 17. Starch content of potato from organic farming relative to conventional farming: + increase, 0 no effect, - decrease. The table summarizes the results of selected studies that compare organic and conventional farming.

Effect	No of studies	References
+	4	(Flis et al., 2012), (Roinila et al., 2003), (Lombardo et al., 2012), (Varis et al., 1996)
0	2	(Jorgensen et al., 2012), (Maggio et al., 2008)
-	1	(Sawicka, 2003)

3.3.1.3 *Protein*

In field trials at Siracusa, Italy Lombardo (2013) found lower total protein in early, organic potato than in conventional potato, while in Serbia Broćić et al. (2008) reported on higher protein content in organic potato than in conventional potato (Lombardo et al., 2013, (Broćić et al., 2008)). In field trials in Poland Sawicka (2003) found no difference in total protein between potato from organic and integrated cultivation (Sawicka, 2003). Lombardo (2012) concluded that there was no difference in protein content of organic and conventional potato grown at Sicily, Italy (Lombardo et al., 2012). Lehesranta et al. (2007) identified proteins which suggested increased stress response in organic potato compared to conventional potato (Lehesranta et al., 2007).

Maggio et al. (2008) found that organic farming increased threonine (24.5 mg/100g) compared to conventional (20.4 mg/100 g) potato, while organic potato contained lower levels of most other amino acids and total amino acids (Maggio et al., 2008). For 9 amino acids there were no differences between the cultivation systems. Ronilia et al. (2003) reported that conventional potato contained more free amino acids than organic potato grown in field trials in Finland (Roinila et al., 2003).

Table 18. Protein content of potato from organic farming relative to conventional farming: + increase, 0 no effect, - decrease. The table summarizes the results of selected studies that compare organic and conventional farming.

Effect	No of studies	References
+	1	(Brocic et al., 2008)
0	2	(Sawicka, 2003), (Lombardo et al., 2012)
-	1	(Lombardo et al., 2013)

3.3.1.4 *Vitamin C*

Vitamin C content has been analysed in potato from field trials by several groups. (Roinila et al., 2003), (Fjelkner Modig et al., 2000), (Rembialkowska, 1999), (Warman and Havard, 1998) in Canada and (Varis et al., 1996) did not find any difference between the cultivation systems. Lombardo et al. (2013) reported that vitamin C content was 45 % higher in organic than in integrated potato one year, while there was no difference the next year (Lombardo et al., 2013). Hajšlová et al. (2005) found that vitamin C was higher in organic than in conventional potato, but with the exception of one year at one farm the differences were not significant (Hajslova et al., 2005). Sawicka (2003) in Poland detected lower levels of vitamin C in organic than in integrated potato (Sawicka, 2003).

Table 19. Vitamin C content of potato from organic farming relative to conventional farming: + increase, 0 no effect, - decrease. The table summarizes the results of selected studies that compare organic and conventional farming.

Effect	No of studies	References
+	2	(Lombardo et al., 2013), (Hajšlová et al., 2005)
0	5	(Roinila et al., 2003), (Fjelkner Modig et al., 2000), (Rembialkowska, 1999), (Warman and Havard, 1998), (Varis et al., 1996)
-	1	(Sawicka, 2003)

3.3.1.5 *Macro elements*

There are relatively few studies on macro element content in organic, integrated and conventional potato. Reports on K content in potato have been published by 6 groups. Wszelaki et al. (2005) in USA and Roinila et al. (2003) reported on more K in organic potato than in conventional potato ((Roinila et al., 2003),(Wszelaki et al., 2005)). Griffiths et al. (2012) and Kristensen et al. (2008) found no difference between the cultivation systems (Griffiths et al., 2012);(Kristensen et al., 2008). Herencia et al. (2011) reported on less K in organic than in conventional potato (Herencia et al., 2011).

(Flis et al., 2012), (Herencia et al., 2011, Wszelaki et al., 2005) and (Warman and Havard, 1998b) reported on higher P content in organic than in integrated and conventional potato. Kristensen et al. (2008) and Roinila et al. (2003) could not find any difference in P levels between potatoes from different cultivation systems ((Roinila et al., 2003),(Kristensen et al., 2008)).

(Griffiths et al., 2012) in USA, (Wszelaki et al., 2005) and (Warman and Havard, 1998a) found higher Mg levels in organically grown potato than in integrated and conventional potato, while (Palmer et al., 2013) found lower Mg level in organic than in conventional potato. Kristensen et al. (2008) and Ronilia et al. (2003) did not find any difference in Mg content in potato from organic and other cultivation systems ((Roinila et al., 2003),(Kristensen et al., 2008)).

(Griffiths et al., 2012), (Kristensen et al., 2008) and Ronilia et al. (2003), reported on no difference in Ca levels between different cultivation systems, while (Flis et al., 2012) and (Warman and Havard, 1998) reported on higher Ca content in organic than in conventional potato. Palmer et al. 2013 found lower Ca levels in organic than in conventional potato (Palmer et al., 2013) .

Kristensen et al. (2008), Hajšlová et al. (2005) and Warman & Havard (1998) could not find any difference in Fe levels between organic and integrated and conventional potato

(Kristensen et al., 2008);(Hajšlová et al., 2005); (Warman and Havard, 1998). Griffiths et al. (2012) detected less Fe in organic than in conventional potato (Griffiths et al., 2012).

3.3.1.6 *Micro elements*

(Griffiths et al., 2012), (Hajslova et al., 2005), (Wszelaki et al., 2005) and (Warman and Havard, 1998) found higher Cu levels in organic than in integrated and conventional potato

Kristensen et al. (2008) detected no difference in Cu, Fe, Mn, Zn, Co and V content of potato from different cultivation systems. They reported that there was no difference in retention of elements in rats fed potato from different cultivation systems, which indicates that there is no effect of the farming system on bioavailability of major and trace elements in rats (Kristensen et al., 2008).

Five groups concluded that Zn levels are the same in potato from different cultivation systems.

There are few reports on other micro elements in potato from different cultivation systems.

3.3.1.7 *Chlorogenic acid*

The secondary plant metabolite chlorogenic acid is an antioxidant present in potato tubers. Hajšlová et al. (2005) reported from field trials that chlorogenic acid was higher at the 2 organic farms (208 and 159 mg/kg) than at the 2 conventional farms (144 and 122 mg/kg) (Hajšlová et al., 2005). Søltoft et al. (2010) in Denmark sampled potato from field trials and analyzed for flavonoids and phenolic acid. They concluded that it cannot be concluded that organically grown potato have higher contents of health-promoting secondary metabolites in comparison with the conventionally cultivated potato (Søltoft et al., 2010b).

3.3.1.8 *Reviews on nutrients in potato*

Lester and Saftner (2011) concluded that accurate and meaningful conclusions comparing the nutritional quality of organic and conventional produce are difficult to ascertain because of the methods used in published, comparative studies (Lester and Saftner, 2011).

Hoefkens et al. (2009) did a meta-analysis of available literature on nutrients in organic and conventional potato and vegetables. They concluded that from a nutritional and toxicological point of view organic potato is not significantly better than conventional potato. The content of vitamin C in conventional potato is higher than in organic potato. Also for the mineral K conventional potato contains higher levels than organic potato. The secondary plant metabolite chlorogenic acid was observed at higher levels in organic than in conventional potato. The nitrate levels in conventional potato were higher than in organic potato. All the paired data on mean concentration in organic and conventional potato are significantly different (Hoefkens et al., 2009).

Table 20. Summary of concentrations of nutrients and contaminants in organic and conventional potato (Hoefkens et al., 2009b).

Compound	Organic		Conventional	
	Number of data points	Mean	Number of data points	Mean
Vitamin C (mg/g)	4	80.48	17	161.66
Ca (mg/g)	9	0.04	48	0.09
K (mg/g)	37	3.08	48	3.64
Chlorogenic acid (μg/g)	7	196.96	8	139.09

In a review Worthington (2001) summarized the results of 41 individual studies on nutritional quality of vegetables. Vitamin C content was 22% higher in organic than in conventional potato, iron content was 21 % higher in organic than in conventional potato and the magnesium content was 5% higher in organic than in conventional potato. There was no difference in phosphorus content of potato from the two cultivation systems (Worthington, 2001).

Woese et al. (1997) reviewed predominantly German literature on nutrient content of organically and conventionally grown food. They concluded that there was no clear difference in nitrate content of potatoes from different cultivation systems. A slight trend towards lower nitrate in organic potato was probably due to differences in the intensity of fertilization (Woese et al., 1997). Woese et al. (1997) were not able to find any differences in mineral or trace elements between potato from organic and conventional cultivation derived from the eight studies they evaluated. Among a large number of studies on vitamin C content of potato from different cultivation systems there was either no difference or higher vitamin C content in organic potato compared to conventional potato. Only two rather old studies reported higher vitamin C content in conventional potato. Studies on dry matter and starch content did not reveal any major difference between cultivation systems (Woese et al., 1997).

3.3.1.9 Glycoalkaloids

Potato contains the glycoalkaloides α-solanine and α-chaconine, which are considered to be natural toxins. The more toxic of the two is α-solanine. Fjelkner-Modig et al. (2000) in Sweden analysed total glycoalkaloides in potato from field experiments, and they determined the level to vary from 0.5 to 2.0 mg/100 g. They found no difference in glycoalkaloid contents between organic and integrated potato (Fjelkner-Modig et al., 2000). Hajšlova et al. (2005) determined total glycoalkaloids in eight potato varieties, organically and conventionally cultivated, during five years at two localities in Bohemia, Czech Republic (Hajslova et al., 2005). The mean glycoalkaloid content was 80.8 ± 44.5 mg/kg in organic and 58.5 ± 44.1mg/kg in conventional tubers. In one of the organically grown varieties there was significantly higher glycoalkaloid concentration in organic than in conventional potato, and in two other varieties there were elevated concentrations of glycoalkaloids in organically grown potato. In further field trials with seven varieties in the Czech Republic Hamouz et al. (2005) were unable to find any difference in glycoalkaloid content between organic and conventional potato (Hamouz et al., 2005).

Abreau et al. (2007) analyzed α-solanine and α-chaconine in organic, integrated and conventional potato from two field trials in Portugal. In one variety the levels were similar, while the second variety had higher glycoalkaloid level in conventional than in integrated and organic potato (Abreu et al., 2007).

At Ohio State University, USA Wszelaki et al. (2005) reported on field trials with one potato variety, organically and conventionally grown in field trials. The content of solanidine, the hydrolysis product of solanine, in conventional potato flesh was 11.6 mg/kg, in organic potato without compost the concentration in the flesh was 28.2 mg/kg and in organic potato with compost the concentration was 28.4 mg/kg. In the potato skin the solanidine content of organic potato was almost the double of the concentration in conventional potato (Wszelaki et al., 2005).

Hoefkens et al. (2009) presented results from a meta-analysis of nutrients and contaminants in potato. They concluded that organically grown potato contain more total glycoalkaloids (77.0 mg/kg) than conventionally grown potato (58.1 mg/kg) (Hoefkens et al., 2009).

3.3.1.10 Nitrate

Sawicka (2003) reported on lower nitrate in organic (44.51 mg/kg) than integrated (47.40 mg/kg) potato (Sawicka, 2003). Also, lower nitrate content in organic potato compared to integrated potato was reported by (Fjelkner-Modig et al., 2000). Herencia et al. (2011) in Spain found lower nitrate concentration in organic potato in two of four years of field trials (Herencia et al., 2011). Broćić et al. (2008) in field trials with 5 cultivars at 2 sites in Serbia reported that in 6 of 10 combinations cultivar/site nitrate content was higher in conventional than in organic potato (Brocic et al., 2008). Also, Hajšlová et al. (2005), Lombardo et al. (2012,2013), Roinila et al. (2003) and Rembialkowska (1999) in Poland reported that nitrate levels were higher in conventional potato during one or more years of field trials. Varis et al. (1996) in Finland could not detect any difference in nitrate levels between the organic, integrated and conventional cultivation systems (Varis et al., 1996).

Table 21 Nitrate content of potato from organic farming relative to conventional farming: + increase, 0 no effect, - decrease. The table summarizes the results of selected studies that compare organic and conventional farming.

Effect	No of studies	References
+	0	
0	1	Varis et al (1996)
-	9	Sawicka (2003), Fjelkner-Modig et al. (2000), Herencia et al. (2011), Broćić et al. (2008), Hajšlová et al. (2005), Lombardo et al (2012), Lombardo et al (2013), Roinila et al. (2003), Rembialkowska (1999),

3.3.1.11 Conclusion on nutrients and bioactive substances in potato

The original research publications cited above are mainly of European origin with a few contributions from USA and Canada included. The review papers presumably use global potato literature as basis for their conclusions. That may explain some differences between the conclusions.

In all but one of the research publications dry matter content is higher in organic than in integrated and conventional potato. Also, most papers report on higher starch content in organic than in conventional potato, but there are also studies that find no difference in starch content between the cultivation systems.

Nine of ten research publications report on higher nitrate content in conventional than in organic potato. Also, in the review by Hoefkens et al. (2009) they found highest nitrate levels in conventional potato (Hoefkens et al., 2009).

Cultivation system does not influence the vitamin C content in most of the cited research publications. This is in accordance with the review of Woese et al. (1997), but Hoefkens et al. 2009) reported on a vitamin C content in conventional potato double the level in organic potato (Woese et al., 1997);(Hoefkens et al., 2009).

In the cited individual publications there are few data from analysis of K, P, Ca, Mg, Fe and trace elements in potato from different cultivation systems. There is no evidence of differences between organic and integrated/conventional potato for these macro- and micronutrients.

In the cited individual publications there are too few data to conclude on any differences in chlorogenic acid content in different cultivation systems. In their review Hoefkens et al. (2009) concluded that the levels of chlorogenic acid is higher in organic than in conventional potato (Hoefkens et al., 2009).

In some studies the level of the natural toxins, glycoalkaloids, are higher in organic than in conventional potato. In most studies the nitrate content is higher in conventional than in organic potato.

3.3.2 Nutrients in fruits

3.3.2.1 Apple

In some of the studies, no effect of production system (organic, integrated and/or conventional) on quality traits investigated were reported (Jørgensen et al., 2012), (Esch et al., 2010), (Peck and Merwin, 2010, Peck et al., 2009), (Valavanidis et al., 2009), (Roth et al., 2007), (Peck et al., 2006), (Roth et al., 2005). Other studies have reported effects of one or several of the production methods applied. Organic production has been found to affect colour, and Jakopic et al. (2012) found that organically produced ‘Golden Delicious’ apples were more yellow than integrated grown apples (Jakopic et al., 2012). Organically produced apples were firmer than apples grown in a conventional or integrated production system (Jakopic et al., 2012), (Konopacka et al., 2012), (Soria et al., 2010), (Reig et al., 2007), (Bertschinger et al., 2004), (Andrews et al., 2001), (Weibel et al., 2000).

For nutrients, various results were observed between the different production systems. Higher contents of dry matter, soluble solids, total and individual sugars and titratable acidity, in organically produced apples were found in several studies (Holb et al., 2012), (Konopacka et al., 2012), (Nagy et al., 2012a), (Roussos et al., 2012), (Adamczyk et al., 2010), (Bertazza et al., 2010), (Soria et al., 2010), (Reig et al., 2007), (Hecke et al., 2006). Others reported on similar contents (Nagy et al., 2012a), (Roussos et al., 2012), (Jonsson et al., 2010), (Soria et al., 2010), (Hecke et al., 2006), (Andrews et al., 2001). Lower contents of dry matter, soluble solids, total and individual sugars and titratable acidity in organically produced apples compared to conventionally or integrated produced apples (Bertazza et al., 2010),(Andrews et al., 2001).

Concentrations of other nutrients, e.g. N, P, S, Ca and B concentration varied with different studies. Significantly higher S and Ca content were found in organic apples in some studies (Bat et al., 2012), (Holb et al., 2012), (Weibel et al., 2000), and significantly higher N, P, B, K and Ca content were found in integrated apples in other studies (Jonssson et al., 2010), (Peck et al., 2009), (Andrews et al., 2001).

For vitamins, antioxidant activity and other bioactive compounds, results are also contradictory. Significantly higher ascorbic acid levels have been reported in organically grown apples compared to conventional production (Nagy et al., 2013), (Bat et al., 2012), (Reig et al., 2007), but contents of vitamins and other bioactive compound have also been shown to vary between cultivar and growing season (Nagy et al., 2013). Bertazza et al. 2010 found higher levels of tocopherol and carotenoids in organic grown apples compared to conventional apples (Bertazza et al., 2010). Higher levels of antioxidant activity in addition to total and individual content of phenolic compounds have been found in organic grown apples (Mikulic-Petkovsek et al., 2010), (Stracke et al., 2009b), (Hecke et al., 2006), (Peck et al., 2006). On the contrary, other studies did not find any significant effect of cultural system on phenolic compounds (Stracke et al., 2009b), (Valavanidis et al., 2009), (Lamperi et al., 2008), (Briviba et al., 2007) or antioxidant activity (Roussos et al., 2012), (Valavanidis et al., 2009), (Reig et al., 2007) in apple.

Aroma compounds have also been investigated in organic and conventional apples. Konopacka et al. (2012) found no effect of production system on aroma compounds (Konopacka et al., 2012). Organic production has, in some cases, been shown to increase antioxidant activity and phenolic compounds in apple peel (Jakopic et al., 2012), (Mikulic-Petkovsek et al., 2010) rather than pulp (Lamperi et al., 2008). In some experiments, phenolic compounds have been found in higher concentrations in apple pulp from organic apples than those produced conventionally (Jakopic et al., 2012), (Veberic et al., 2005).

3.3.2.2 *Pear*

There are few studies on the effect of production system on nutrients in pears. In a study on soluble solids and pH, no effect of production systems was found (Balas, 2003). Increased dry matter content (Bertazza et al., 2010), significantly higher levels of phenolic compounds ((Bertazza et al., 2010), (Carbonaro et al., 2002)) in addition to a higher ascorbic acid concentration (Bertazza et al., 2010) have been reported in organically compared to conventionally grown pears. On the contrary, Carbonaro et al. 2002 reported on no significant differences in content of ascorbic acid or citric acid in pears from conventional and organic production systems (Carbonaro et al., 2002). Tocopherol and carotenoid levels were in one experiment significantly lower in organically than in conventionally produced pears (Bertazza et al., 2010).

3.3.2.3 *Plum*

Only one paper was found comparing organic and conventional plum growing. Organically grown plums were significantly higher in K, Mg and Zn compared to plum from conventional cultivation, but Na and Cu contents were higher in conventional apples. No significant effect of production system was found on fiber or total sugar content, ascorbic acid or vitamin E, except for γ-tocopherol, where higher content was observed in conventionally than in organically grown plums. This was also the case with vitamin K. β-carotene was higher in organic plums, but the total content of polyphenols and quercetin was higher in conventional than in organic plums. On the contrary, myricetin and kaempferol content was highest in organic grown plums (Lombardi-Boccia et al., 2004).

3.3.2.4 *Cherry*

Only one paper comparing organically and conventionally produced sour cherries was found. There was no significant effect of production system on chlorogenic acid and rutin concentration (Nagy-Gasztonyi et al., 2010).

3.3.2.5 *Conclusion on nutrients in fruits*

Organic production seems to have positive effect of several of the quality traits analysed, especially firmness, dry matter, ascorbic acid, antioxidant activity and phenolic compounds. Nevertheless, the results do also show a large variation between the different production methods, which could be due to the many variables in the trials (e.g. years, with various climatic conditions, genetic variations). Long term studies with fewer variables would probably give a better picture on the effect of production systems on nutrients in fruits. Only one study on nutrients in plum and one on nutrients in cherry were found. This is not sufficient to draw any conclusion.

3.3.3 Nutrients in berries

3.3.3.1 *Strawberry*

Various results have been found in studies comparing the effect of organic and integrated/conventional production systems on strawberry quality. Organically grown strawberries have been shown to have higher colour intensity than conventionally produced strawberries (Crecente-Campo et al., 2012), (Cayuela et al., 1997), which is associated with higher amounts of anthocyanins. Increased concentration of soluble solids (Kahu et al., 2010), (Magnani et al., 2009), (Tonutare et al., 2009), dry matter ((Tonutare et al., 2009), (Cayuela et al., 1997)), ascorbic acid, anthocyanins, ellagic acid, phenolic compounds (Tarozzi et al., 2010) and antioxidant activity ((Kristl et al., 2013), (Fernandes et al., 2012), (Jin et al., 2011), (D'Evoli et al., 2010), (Magnani et al., 2009), (Hakkinen and Torronen, 2000)) have also been reported in organically compared to conventionally grown strawberries. Different production systems had no effect on firmness, soluble solids, titratable acidity, ascorbic acid (Kahu et al., 2010), minerals (Cayuela et al., 1997) , antioxidant activity ((Tarozzi et al., 2010), (Hargreaves et al., 2008)) and phenolic compounds ((Roussos et al., 2012), (Cayuela et al., 1997)). Mineral content has been found to be more dependent on genetic variation (cultivar) than the production system. One study showed that organically grown strawberries had significantly higher content of Cu, and integrated fruits had significantly higher content of P, K, Mg, Fe and Mn (Kristl et al., 2013). On the contrary, another study showed higher content of Ca, P, Fe and Cu in organic strawberries compared to conventional grown berries (Tarozzi et al., 2010). Baiamonte et al. (2010) analyzed two strawberry cultivars, grown organically and integrated for two years, and found significant interactions between the variables. The authors concluded that it was impossible to isolate each variable's effect due to variations between the many input variables in the study (Baiamonte et al., 2010).

3.3.3.2 *Red raspberry*

For red raspberries, production system has been shown to have a significant effect on antioxidant activity, with higher levels in organic berries (Jin et al., 2012), while other studies have shown no effect of production systems ((Sablani et al., 2010), (Skupien et al., 2011)). Analyzing three red raspberry cultivars, Skupien et al. (2011) did not find any significant effect of production system (organically or conventionally) , and they concluded that the cultivar response within the specific site conditions was more important than the production system (Skupien et al., 2011).

3.3.3.3 *Black and red currant*

In black and red currants, production system has been shown to affect different quality traits. *Ribes* berries grown organically contain significantly higher ascorbic acid concentration (Wojdylo et al. 2013, Kahu et al., 2009, Kazimierczak et al., 2008), total phenolics (especially anthocyanins), and antioxidant activity (Wojdylo et al. 2013, Kazimierczak et al., 2008) than fruit grown conventionally. One study found higher anthocyanin content in conventionally grown red currants compared to organically grown berries, while organic berries had 2.7 times higher content of oligomeric procyanidins than berries from conventional cultivation (Wojdylo et al. 2013). This is somewhat in agreement with Anttonen and Karjalainen (2006), who found significant differences in major phenolic compounds in black currants between farms, but could not separate organically grown berries from those grown conventionally (Anttonen and Karjalainen, 2006).

3.3.3.4 *Conclusion on nutrients in berries*

Results from the included studies can be interpreted as positive for organic production on quality traits and nutrients in berries, e.g. antioxidant activity, anthocyanins, ellagic acid, ascorbic acid, soluble solids and some minerals. Nevertheless, some of the studies showed no effect of production system, or even lower values in organically than in conventionally produced berries.

3.3.4 Nutrients and bioactive substances in vegetables

3.3.4.1 *Tomato*

Several studies have been carried out on organic and conventional tomato production with many variables in the same study; cultivar, ripening stage and year of production ((Hallmann, 2012), (Ordonez-Santos et al., 2011), (Durazzo et al., 2010), (Gravel et al., 2010), (Rodriguez et al., 2010), (Ordonez-Santos et al., 2009), (Scalzo et al., 2008), (Chassy et al., 2006). Different methods for analysing antioxidant activity have been employed (Nobili et al., 2008). Results from these studies show that quality traits like soluble solids, lycopene, β-carotene, vitamin C, acidity, total and individual phenolic compounds and antioxidant activity are influenced by production system. Some studies reported on significantly higher concentrations in organically compared to conventionally produced tomato of soluble solids, vitamin C, antioxidant activity (Hallmann, 2012, Ordonez-Santos et al., 2011, Ordonez-Santos et al., 2009), (Caris-Veyrat et al., 2004), β-carotene (Nobili et al., 2008), flavonoids, quercetin and kaempferol (Hallmann, 2012, Mitchell et al., 2007, Chassy et al., 2006). Others reported on significantly lower concentration in organic compared to conventional tomato of lycopene (Botrel et al., 2012, Rossi et al., 2008, vitamin C (Rossi et al., 2008), chlorogenic acid, caffeic acid, quercetin (Nobili et al., 2008) and soluble solids (Rodriguez et al., 2010).

One paper analysed minerals and reported on higher contents of P and Ca in organically grown tomatoes, but higher N and Na concentrations in conventionally grown tomatoes (Colla et al., 2002). Significantly higher content of Mn has been reported in organically grown tomato fruits (Ordonez-Santos et al., 2011). Other studies did not find any effects of production system on the content of phenolic compounds, lycopene, β-carotene or vitamin C in tomato ((Durazzo et al., 2010), (Gravel et al., 2010)).

3.3.4.2 Brassica vegetables

Species representing *Brassica* vegetables in the studies selected were head cabbage (white and red), broccoli, Brussel sprouts, cauliflower, kale and swede ((Kapusta-Duch and Leszczynska, 2013), (Bavec et al., 2012), (Bender and Ingver, 2012), (Kapusta-Duch et al., 2012), (Bimova and Pokluda, 2009), (Fjelkner Modig et al., 2000)). Production system was in some of the studies found to influence the content of nutrient compounds significantly, but the results could at the same time not be related to one specific production system ((Gravel et al., 2010), (Bavec et al., 2012), (Kapusta-Duch et al., 2012), (Picchi et al., 2012), (Martinez-Tome et al., 2011), (Scalzo et al., 2008), (Fjelkner Modig et al., 2000)). Other studies did find effects of production system. Two studies reported that organic fertilization had either similar, or an improving effect on quality traits in cabbage (antioxidant capacity) and broccoli (ascorbic acid, carotene, chlorophyll and sugar content) compared to conventional mineral fertilization ((Das et al., 2013), (Bimova and Pokluda, 2009)). Significantly higher dry matter (Bender and Ingver, 2012), vitamin C and β-carotene content have been reported in organically grown Brussel sprouts, swede ((Kapusta-Duch and Leszczynska, 2013), (Bender and Ingver, 2012)) and broccoli (Zapata et al., 2013). On the contrary, lower antioxidant activity has been reported for organically grown white cabbage (Kapusta-Duch et al., 2012), and no significant effect of production system was reported for phenolic content and antioxidant activity in broccoli (Zapata et al., 2013).

3.3.4.3 Carrot

Results from two studies on carrots showed that conventionally grown carrots had significantly higher nitrate concentration than organically grown carrots ((Wrzodak et al., 2012), (Bender et al., 2009)). Dry matter, total sugars, soluble solids, carotenoids, polyacetylenes, P, K, Ca and Mg concentrations have been found not to differ significantly between the different cultivation systems ((Wrzodak et al., 2012), (Soltoft et al., 2011), (Soltoft et al., 2010b), (Bender et al., 2009), (Fjelkner Modig et al., 2000)). On the contrary, other studies have reported significantly higher dry matter content in organic carrots (Bender and Ingver 2012, (Fjelkner Modig et al., 2000), while β-carotene, vitamin C and N content was reported to be significantly lower in organically than conventionally grown carrots ((Wrzodak et al., 2012), (Bender et al., 2009)). The polyacetylenes falcarindiol, falcarindiol-3-acetate and falcarinol have also been studied, where production system showed no significant effect on the concentration of polyacetylenes (Søltoft et al., 2010b, Søltoft et al., 2010a).

3.3.4.4 *Lettuce*

Polyphenol content, quercetin-3-O-glucoside and chicoric acid in lettuce were in two studies reported to be higher in organic compared to conventional production ((Heimler et al., 2012), (Rajashekar et al., 2012)), but in one of these studies, production system did not seem to affect the flavonoid, hydroxycinnamic acid or anthocyanin concentrations (Heimler et al., 2012). In two studies no significant effects of production system for total phenolic content or antioxidant capacity in lettuce were reported ((Rajashekar et al., 2012), (Young et al., 2005)).

3.3.4.5 *Onion*

In one study of the effects of production system on Ca, Mg, Si, B and Se content in organically and conventionally grown onions, all nutrients, except for Mg, were found in higher concentrations in conventionally produced onions (Gundersen et al., 2000). One paper analyzed phenolic compounds in organically and conventionally produced onions, and no significant effect of production system was found (Søltoft et al., 2010a).

3.3.4.6 *Nitrate in vegetables*

In a three year study, higher nitrate content was reported in conventional (349.9-554.4 mg/kg) compared to organic (259.1-374.7 mg/kg) carrots. Nitrate content also varied with cultivar (Wrzodak et al., 2012). On the contrary, Fjelkner-Modig et al. (2000) reported higher nitrate content in organic (3.3 mg/100g) compared to integrated (2.6 mg/100g) carrots (Fjelkner-Modig et al., 2000). Due to their high nitrate content, poorer quality has been reported in conventionally grown carrots. In the same study, nitrate was not even detected in organic carrots (Bender et al., 2009). In white cabbage, substantially higher nitrate content has been reported in organic (12.7 mg/100g) compared to integrated (3.6 mg/100g) cabbage (Fjelkner-Modig et al., 2000). This is in accordance with Bavec et al. (2012), who reported significantly higher nitrate content in organic (217.7 mg/kg) cabbage when comparing four different farming systems (conventional, integrated, organic and biodynamic) (Bavec et al., 2012). On the contrary, biodynamic cabbage had lower nitrate content (104.7 kg/kg), and cabbage grown conventionally or integrated did not differ significantly from the organic or biodynamic cabbage. Lucarini et al. (2012) reported on 1.3-2 times less nitrate accumulation in biodynamically than organic lettuce, where nitrate levels also varied with cultivar (Lucarini et al., 2012).

3.3.4.7 *Conclusion on nutrients and nitrate in vegetables*

Reviewing the selected studies on the effect of different production systems on nutrients in vegetables resulted in various, and less clear results. Conventional and organic production systems seem to have both positive and no effect on many of the nutrients analyzed. Therefore, it is not possible to draw a clear conclusion on the effect of production system on nutrients in vegetables. Also, the nitrate levels in some studies are highest in organic and in other studies the nitrate levels are highest in conventional vegetables.

3.3.5 Nutrients in cereals

3.3.5.1 Cereals and nutritional quality

Cereals are important sources of energy, protein, minerals (in particular Fe, Zn) and some vitamins (B- and E vitamins) in human nutrition. Cereals are also an important source for fiber. In most developed countries, Norway included, the intake of fibers are lower than the recommendations, and consumption of whole grain products/high fiber products of cereals are stressed from the nutritional authorities. In recent decades, the contents of polyphenols and other bioactive compounds with antioxidant activity, have been investigated in cereals. As the intake is high, cereals may represent a good source of such bioactive compounds in human nutrition.

It is well known that wide variations can be found in chemical compositions of cereals, due to genetic variation between varieties, impact of environmental conditions and also due to genotype*environment interactions. Large variation is found in protein content, and the availability of N in the soil during plant development is a major cause for this variation (see (Shewry, 2011) for review). Limited amounts of plant available N in the soils give lower protein contents in the grains, however, this relationship are also affected by yield level. Hence, lower grain yield will normally give higher protein content at similar soil N levels. Not only total N available during the growth season, but also the N availability at different growth stages may affect protein content (see Gooding 2010 for review). Generally, increased N availability at later growth stages may efficiently increase protein contents, whereas increased N availability in the earlier stages (at tillering and stem elongation) will affect grain yield more strongly. Furthermore, it is also known from wheat and barley that N availability for the plants not only affect the protein content but also the protein composition in the grains. Increased N fertilisation giving a higher protein content may increase the storage proteins, particularly the rolamins more than the structural and metabolic proteins (albumins and globulins), affecting the amino acid composition and the biological value of the protein (see Shewry, 2011for review). It is commonly found lower proportion of lysine (in g/100g protein) and lower feed value of the protein when the protein content in wheat and barley grains are higher ((Mossé and Huet, 1990), (Mossé et al., 1985)). This relationship is not found in oats, having a low proportion of the protein as prolamins.

Genetic variation between varieties is also found for concentration of other nutrients in grains, as the essential micro minerals Fe and Zn. However, the impacts of environmental factors affecting the concentration of these nutrients are less understood. It is suggested that factors increasing yield by giving well developed and plump grains may increase the starch content more, having a diluting effects on other compounds as minerals and vitamins ((Shewry, 2009), (Xu et al., 2011)).

3.3.5.2 Comparisons of organic and conventional cereals.

An overview of the selected peer-reviewed research articles together with a brief description of the study type and design as well as the main results are given in Appendix 2B (7.4) table 12. In total, 28 research articles were included. Wheat was the object of 25 of these studies, and only 2 studies were on oats. One of the selected articled was studying more than one cereal (wheat, barley and oats). The majority of the selected studies (23) were done in Europe, and five of these were carried out in Northern Europe. The other 5 studies were done in North America. The majority of the studies were either analysing protein content (and parameters related to protein content as protein composition and amino acid composition) (18 studies) or analysing content and composition of macro- and/or micro minerals (9 studies). One of these was on selenium in oats (Eurola et al., 2004). Four studies were analysing bioactive compounds such as phenolic acids and carotenoids ((Zuchowski et al., 2011), (Roose et al., 2009), (Langenkamper et al., 2006), (Stracke et al., 2009a)) and one study was on fiber (beta-glucans) in oats (Saastamoinen et al., 2004). Hence, the existing research literature on nutrient content in cereal is too limited to be able to make sound comparisons between production systems for many of the nutrients or health related compounds. Therefore, the results are summarized and discussed only for protein and mineral contents.

Protein content

The majority of the selected studies analysing the differences in protein content between organically and conventionally produced wheat were also analysing the processing quality for bread. As processed products were not included in the criteria set up for this report, these results are omitted. The included studies showed that the protein content was higher in conventional than in the organic system in 15 of the studies ((Arncken et al., 2012), (Ceseviciene et al., 2012), (Zuchowski et al., 2011), (Mateos et al., 2010), (Neacsu et al., 2010), (Hildermann et al., 2009), (Ingver et al., 2008), (Mader et al., 2007), (Krejcirova et al., 2006), (Langenkamper et al., 2006), (Lueck et al., 2006), (Hanell et al., 2004), (L-Baeckstrom et al., 2004), (Strobel et al., 2001), (Eltun, 1996a)). One of the studies reported no differences between systems (Mason et al., 2007a), whereas in one study, the protein content was highest in the organic system (Nelson et al., 2011a, Annett et al., 2007).

One of the selected studies was also studying changes in protein composition in organic and conventional wheat (Krejcirova et al., 2006), and they reported lower contents of glutenins and higher contents of albumins and globulins in the organic what samples than in conventional wheat. Amino acid composition was analysed in one study (Hanell et al., 2004), who found higher content of the essential amino acids threonine and leucine in the organic samples.

Minerals

Variable results were seen in the studies measuring the contents of minerals in organic and conventional grain samples. In four of the studies (approximately half of the studies), no differences in mineral contents were documented ((Mader et al., 2007), (Turmel et al., 2009), (Langenkamper et al., 2006), (Wisniowska-Kielian and Klima, 2006)), but some trends towards higher contents in organic samples was found. In the other studies, higher contents were found in organic samples for some minerals ((Ciolek et al., 2012), (Vrcek and Vrcek, 2012), (Nelson et al., 2011b), (Strobel et al., 2001)), but this was not consistent across the studies. Significantly higher contents of Fe, Mg, Ca, Zn in the organic samples was found in two or more of the studies. The two studies analysing Se ((Eurola et al., 2004),(Nelson et al., 2011b)) both found higher contents in conventional samples, which could be expected as Se in grains are mainly linked to the protein fraction.

3.3.5.3 Reviews on nutrient content in cereals

Several reviews have summarized the differences in nutrient content in organic and conventional produced food plants, but only a few have included cereals ((Woese et al., 1997), (Worthington, 2001), (Magkos et al., 2003), (Hunter et al., 2011), (Smith-Spangler et al., 2012)). In several of these works ((Worthington, 2001), (Hunter et al., 2011), (Smith-

Spangler et al., 2012)) the differences in concentration between organic and conventional samples were calculated and subjected to new statistical data analysis.

Woese et al. (1997) reported a trend towards lower protein content in organically produced cereals (Woese et al., 1997). Changes in amino acid composition were also seen, but the number of studies was low and a general statement could not be given. No differences could be found in the concentration of minerals or vitamin B between organic and conventional produced cereals in this review. Also Worthington et al. (2001) and Magkos et al (2003) reported lower protein content and better protein quality (higher proportion of essential amino acids) in organic cereals ((Worthington, 2001),(Magkos et al., 2003)) . Hunter et al. (2011), reviewed differences in the concentration of micronutrients between organic and conventional plant products. They found no differences for cereals whereas higher concentrations were found in the organic fruits, vegetables and legumes (Hunter et al., 2011). The recent review of Smith-Spangler et al. (2012), also reported on lower protein contents in organic samples in most of the reviewed articles. However, from their statistical treatments of the calculated differences, significant effects were only found for phosphorus and total phenols, both having a higher concentration in the organic samples (Smith-Spangler et al., 2012).

It should be noted that these reviews comparing the nutrient content in organic and conventional food plant products have included relatively few research articles on cereals. All of these are included in the present literature study. This reflects that the existing literature on nutritional quality in organic and conventional cereals is more limiting than for other food plants.

3.3.5.4 *Conclusion on nutrients in cereals.*

There are convincing data to conclude that the protein content is commonly lower in organically produced wheat compared to conventional wheat. Similar trends are found also for oats and barley, but the number of studies is low. For other nutrients, the literature is too limited for any sound conclusions to be drawn.

3.3.6 Nutrients in grasses

The literature search on nutrient included very few studies comparing the nutrient content in leys (or other types of grasslands) comparing nutrient contents in the harvests or in silages when comparing organic and conventional production systems. Among the few research articles identified, several aimed at analysing the animal products (mostly milk), or at the nutrient balances for the entire system. However, some data on botanical composition of the leys or nutrient composition of the silages are given. Several of the research articles reported higher proportions of clover in the organic systems, as can be expected ((Adler et al., 2013), (Adler and Steinshamn, 2010), (Eltun, 1996a), (Pettersson et al., 1998), (Gustafson et al., 2007). One study (Geherman et al., 2003) reports no differences, but this may be explained by relatively small differences in the organic and conventional farms that were selected for this study. Less consistent differences were found in chemical composition of the harvests or silages. Harvest time and field differences caused more variation in chemical composition than the production systems (organic or conventional) (Pettersson et al., 1998). Because of the low number of studies, sound conclusions cannot be made on differences in nutrient contents between organic and conventional leys/forage.

3.3.7 General discussion and conclusion, nutrient content in organic and conventional plant products

The existing literature (research articles and reviews) comparing differences in nutritional quality in organic and conventional food plants do not show consistent results. Although the findings in many studies are in favour of organically produced products, for some nutrients the documentation is weak due to the large variations in nutrient contents found within both systems. This can be expected as there is often a lack of consistency in the study designs (i. e. rotations, other management practices), different varieties are used in the different studies, and also differences in physiological maturity stages of the products analysed or differences in the storage conditions prior analysing may have occurred. Among these the genetic component of variation linked to the varieties used are often found to have strong impacts on the concentration of nutrients ((Nagy et al., 2013), (Nagy et al., 2012b)). Furthermore, environmental impacts due to different soils and weather conditions ((Nagy-Gasztonyi et al., 2010), (Stracke et al., 2009a)) have strong influence, and they are causing complex interactions, making the interpretations of the results difficult.

In many of the studies, differences in nutritional quality are discussed in relation to fertilisation practices in the organic and conventional systems, and the availability of nutrients during plant development are expected to be a main factor affecting chemical composition of the harvested plant products. Differences in the availability of N during plant growth may directly affect the concentration of N compounds (i.e. nitrates, amino acids and protein) or indirectly by affecting yield quantity and thus chemical composition through a variety of complex biological mechanisms. Different plant protection strategies are also among the main differences between organic and conventional systems, and may have large impacts on yield and thus chemical composition. Some authors suggest that higher stress levels found in organically grown fruits compared to conventional or even integrated production could cause higher levels of some of the quality traits analyzed ((Jakopic et al., 2012),(Veberic et al., 2005)).

The nutrient content in different crops may be affected differently by production factors, as should be expected when comparing i.e. cereal grains, leafy vegetables or root/tuber crops. The selected literature varies a lot in the number of studies on various crops, as well as of the various nutrients. Apple, strawberry, potato, *Brassica* vegetables and wheat were the most studied crops, and protein, nitrates, minerals, vitamins and known bioactive compounds were the most analysed compounds. Even if a high number of hits were identified in the library search, only a few of these met the selection criteria, which were disappointing. Thus, the existing literature is still limiting to be able to compare the main essential nutrients in plant products grown in organic and conventional systems.

Large variation in nutrient content was found for both systems. However, some differences or trends could be found across plant products, and which can be biologically plausible due to differences of the systems. Higher contents of dry matter in organic compared to conventional products were found in many of the studies on potatoes, fruits and berries, and in some cases also for vegetables. Higher contents of nitrogen containing compounds have been found in conventional plant products compared to organic. In cereals, most studies reported higher protein contents in conventional production. In potato as well as for some leaf and root vegetables, higher nitrate contents in conventional products have been shown in some studies, whereas others found no differences. Ascorbic acid is analysed in many of the studies of fruits, berries and potato. Variable results are found but the majority of the studies report either no differences or higher average contents in the organic products.

3.4 Comparison of content of environmental contaminants

3.4.1 Organic chemical contaminants

The available information comparing the occurrence of organic contaminants in products from organic farming and conventional farming is very limited. The few studies comparing organic contaminants in products from organic and conventional grown food plants identified in the search dealt with PCBs (Witczak and Abdel-Gawad, 2012) and old pesticides that have been banned in Europe for many years, like DDT and HCH ((Witczak and Abdel-Gawad, 2012), (Hilber et al., 2008), (Gonzalez et al., 2005). VKM did not identify any studies comparing the occurrence in organic versus conventional farming for several important organic contaminants such as dioxins, PAHs, and phthalates. The information related to emerging contaminants like PFOS, linear alkylbenzenesulfonate (LAS) etc. are probably also very limited or non-existing.

Also the available review papers contains very little, if any discussion on organic contaminants in conventional versus organic grown plant derived foods and future surveys of the content of these contaminants in organic and conventional crops has been recommended (Rembialkowska, 2004).

The source of organic contaminants in soil is probably more related to sources that are not influenced by the differences in agricultural practises between organic and conventional farming, such as prior use of the soil, nearby industry or roads, possible contamination of irrigation water, or airborne pollution, even though manure may also be a source. Furthermore, the uptake of most organic contaminants from the soil is very low or negligible. A large difference in levels of organic contaminants in plant food from organic and conventional grown products is therefore not to be expected.

Residues of pesticides are covered in document “Comparison of organic and conventional food and food production, Part V: Human health – pesticide residues” (11/007-5).

3.4.2 In-organic chemical contaminants

Cereals and vegetables are important sources for dietary intake of certain heavy metals due to the high consumption of these food items. There are most studies comparing the occurrence of cadmium (Cd) and lead (Pb) in wheat and potatoes and fewer studies of other metals and other food commodities. Table 22 summarises studies comparing the concentrations of cadmium and lead in commodities for which more than 1 study has been identified and data from all the identified studies comparing the occurrence of selected heavy metals cadmium, lead, mercury, arsenic and nickel in unprocessed food plants from conventional and ecological farming are compiled in Appendix 2. The data does not provide any basis for a firm conclusion on the potential difference in levels of heavy metals between organic and conventional grown food plants.

Table 22. Comparative studies of heavy metal content in unprocessed food plants for which combination of contaminant and plant there are several studies. Higher is number of studies showing higher concentrations in organic compared to conventional grown plants, while lower is the opposite.

Cadmium (Cd)			
Plant	**No. of studies**	**Difference organic vs conv.**	**References**
Wheat	0	Higher	
	4	No diff	(Hoogenboom et al., 2008), (Harcz et al., 2007), (Malmauret et al., 2002), (Jorhem and Slanina, 2000)
	3	Lower	(Vrcek and Vrcek, 2012), (Cooper et al., 2011), (Rossi et al., 2008)
Potatoes	0	Higher	
	4[1]	No diff	(Hajslova et al., 2005), (Fjelkner-Modig et al., 2000), (Jorhem and Slanina, 2000), (Rembialkowska, 1999)
	2	Lower	(Flis et al., 2012), (Kristensen et al., 2008)
Tomatoes	1	Higher	(Rossi et al., 2008)
	0	No diff	
	1	Lower	(Bressy et al., 2013)
Carrots	0	Higher	
	4	No diff	(Kristensen et al., 2008), (Malmauret et al., 2002), (Fjelkner-Modig et al., 2000), (Jorhem and Slanina, 2000)
	2 [2]	Lower	(Domagala-Swiatkiewicz and Gastol, 2012), (Gaweda et al., 2012)
Onion	0	Higher	
	2	No diff	(Fjelkner-Modig et al., 2000), (Gundersen et al., 2000)
	0	Lower	
Peas	0	Higher	
	3	No diff	(Kristensen et al., 2008), (Fjelkner-Modig et al., 2000), (Gundersen et al., 2000)
	0	Lower	
Lettuces	0	Higher	
	2	No diff	(Hoogenboom et al., 2008), (Malmauret et al., 2002)
	0	Lower	
Lead (Pb)			
Plant	**No. of studies**	**Difference organic vs conv.**	**References**
Wheat	2	Higher	(Harcz et al., 2007), (Rossi et al., 2006)
	4	No diff	(Cooper et al., 2011), (Hoogenboom et al., 2008)
	1	Lower	(Vrcek and Vrcek, 2012)
Potatoes	0	Higher	
	4	No diff	(Flis et al., 2012), (Hajslova et al., 2005), (Fjelkner-Modig et al., 2000), (Jorhem and Slanina, 2000)
	0	Lower	
Carrots	1	Higher	(Malmauret et al., 2002)

	3[2]	No diff	(Domagala-Swiatkiewicz and Gastol, 2012), (Fjelkner-Modig et al., 2000), (Jorhem and Slanina, 2000)
	1	Lower	(Gaweda et al., 2012)
Onion	0	Higher	
	2	No diff	(Fjelkner-Modig et al., 2000), (Gundersen et al., 2000)
	0	Lower	
Peas	0	Higher	
	2	No diff	(Fjelkner-Modig et al., 2000), (Gundersen et al., 2000)
	0	Lower	
Lettuces	0	Higher	
	2	No diff	(Malmauret et al., 2002), (Hoogenboom et al., 2008)
	0	Lower	

[1] no difference expressed as fresh weight basis, but lower Cd in organic when expressed on a dry weight basis.[2] measured in juice from pressed vegetables.

For cadmium, most studies show either no difference or slightly lower levels in plants from organic grown vegetables. But higher Cd levels in organic grown tomatoes (Rossi et al., 2008) and spinach (Malmauret et al., 2002) have also been reported. For lead, the available data comparing the different cultivation forms are highly variable and indicate that there are no systematic differences in lead in plants from organic and conventional grown food plants (Table 22).

Worthington (2001) did a new statistical analysis of reported studies comparing the concentrations of heavy metals and other components in organic and ecological grown fruits, vegetables and grain and found lower amounts of heavy metals in organic crops compared to conventional ones (Worthington, 2001). The paper does, however, not provide the data for heavy metals. Furthermore, the study has been criticised for an inappropriate use of statistics (Matthews, 2002). The same approach was used by Hoefkens et al., (2009) who could not find any differences in heavy metal content between organic and conventional crop. They concluded however that there is uncertainties related to the available studies and that more data from controlled paired studies are needed to evaluate the potential differences in heavy metal concentrations (Hoefkens et al., 2009). The lack of sufficient high quality data for a comparison of heavy metal concentrations in organic and conventional grown crop was also a main conclusion in other reviews (Rembialkowska, 2004), Pussemier et al., 2006a).

3.4.2.1 Discussion on in-organic contaminants

The occurrence of metals in the soil may both depend on the agricultural factors such as fertilizers and non-agricultural factors such as geology, industrial waste, air pollution etc. The levels of metals, including heavy metals, in plants are known to depend on both crop plant, soil concentrations of the metals, chemical forms, and a range of soil parameters such as organic matters, pH, humidity, temperature etc. Some of these soil parameters, such as pH, and organic matter content are probably affected by farming practices over time.

3.5 Comparison of content of mycotoxins

Mycotoxins are poisonous chemical compounds produced by certain fungi. Some of these are produced by fungi infecting plants in the field during the growing season, while others are caused by fungi growing on plant products postharvest. Contaminated crops may cause a health risk when consumed by humans and livestock in food and feed products. Species within the fungal genera *Fusarium*, *Penicillium*, *Aspergillus* and *Alternaria* are important mycotoxin producers. The most important toxins in temperate growing regions in terms of health hazards are:

- deoxynivalenol (DON) and other trichothecenes (eg nivalenol (NIV), T2-toxin, HT2-toxin), zearalenon (ZEA), produced by *Fusarium* spp.
- ochratoxin A (OTA), produced by *Penicillium* spp. and *Aspergillus* spp.
- patulin produced by *Penicillium* and *Aspergillus* spp.

Production of mycotoxins depends primarily on temperature, humidity, host species and varieties (cultivars), agronomy and other environmental conditions. An important question is whether the cultivation system has an impact on the development of mycotoxins. Since synthetic fungicides and mineral fertilizers are not used in organic production it has been questioned whether organic crops may be more affected by fungal infection and mycotoxin contamination.

Except for one field trial carried out during 1990-1993 (Eltun, 1996a) and a farm survey carried out during 2002-2004 (Bernhoft et al., 2010), both in cereal grains, there are no Norwegian investigations comparing mycotoxins in plant materials from organic and conventional production. Several surveys and studies from other North European countries have been identified in the search of peer-reviewed literature on comparisons of mycotoxins in organic and conventional (or integrated) produced plant products, mainly in cereals (Appendix 2D (Table 17). A total of 45 research papers were included. Only a few of these studies are controlled comparative field trials. Most are farm surveys that provide information about the differences in mycotoxin contamination, as well as concentration levels of mycotoxins, in “raw materials” grown in organic and conventional production systems at the same time and in the same region. Data on mycotoxins in food and food products (flour, breakfast cereals, bread, pasta, beer, wine etc), have not been included, unless they were part of a “raw materials” study and the results were not possible to extract separately.

3.5.1 Cereals

Under Norwegian/Nordic/European conditions, cereals are the agricultural commodities that most commonly are contaminated by mycotoxins. Mycotoxin contaminations of cereals are widespread and a considerable increase in DON contamination in Norwegian cereals during the last decade was reported in a recent risk assessment carried out by the Norwegian Scientific Committee for Food Safety (Bernhoft et al 2013). In addition to an evaluation concerning human and animal health, the report also considered the different factors affecting fungal infection and mycotoxin production in cereal grains. The effect of different production factors are not repeated here.

3.5.1.1 Deoxynivalenol (DON)

In total, 27 studies comparing DON content in organically and conventionally produced cereals have been included. Some studies compared DON content in more than one cereal species. Organic and conventional wheat was included in 22 of these, oats in six, rye in five and barley in four studies (altogether 38 comparisons).

Table 23. Content of deoxynivalenol (DON) in cereals from organic farming relative to conventional farming: + increase; 0 no effect; - decrease. The table summarizes the results of studies that compare DON contamination (mean and/or median concentration levels and/or contamination frequencies) in the two farming systems. Some studies compared more than one cereal species.

Effect	No of studies	References
+	4	(Twarużek et al., 2013)(oats); (Perkowski et al., 2007)(wheat with fungicide in in conventional); Bakutis et al 2006 (barley); (Marx et al., 1995) (rye)
0	17	Kuzdralinsky et al 2013 (oats); Vidal et al 2013 (oats, wheat); Bernhoft et al 2010 (barley); Edwards 2009c (wheat); Edwards 2009a (barley); Hoogenboom et al 2008 (wheat); Vanova et al. 2008 (wheat); Harcz et al 2007 (wheat); Mäder et al 2007 (wheat); ; Champeil et al 2004 (wheat); Griesshaber et al 2004 (wheat); Hietaniemi et al 2004 (oats); Birzele et al 2002 (wheat with fungicide in conventional); Malmauret et al 2002 (wheat, barley); Berleth et al 1998 (wheat, rye); Eltun 1996a (oats, wheat); Marx et al 1995 (wheat)
-	11	Blajet-Kosicka et al 2014 (rye); Lacko-Bartosova and Kobida 2011 (wheat); Bernhoft et al 2010 (oats, wheat); Meister 2009 (wheat, rye); Perkowski et al 2007 (wheat without fungicide in conventional); Bakutis et al 2006 (wheat); Pussemier et al 2006b (wheat); Schneweis et al 2005 (wheat); Birzele et al 2002 (wheat without fungicide in conventional); Döll et al 2002 (wheat, rye); Schollenberger et al 2002 (wheat)

The majority of the studies found no significant differences in DON content in cereals from the two cultivation systems (Table 23). Eleven studies reported lower DON content in organic compared to conventional cereals and four studies reported the opposite. Perkowski et al 2007 found considerably higher DON content in conventional wheat without chemical protection compared to organically produced wheat; however, lower content was found in conventional than in the organic wheat when fungicides were used in the conventional production (Perkowski et al., 2007). Twaruzek et al 2013 found higher DON content in organic than in conventional oats (Twarużek et al., 2013), Bakutis et al 2006 reported higher concentrations in organic than in conventional barley, and Marx et al 1995 found higher DON contamination in organic than in conventional rye (Marx et al., 1995).

Many of the investigations (Table 23) reports low DON concentration levels in grain from both cultivation systems; often the levels did not exceed the EU limits for food: 1250 µg/kg in wheat, barley and rye and 1750 µg/kg in oats.

In a review of seven studies included in a “summary effect size calculations”, Smith-Spangler et al (2012) reported lower levels and lower risk for DON in organic wheat than in conventional, although the authors pointed out that one large study, that could not be included in the calculations, showed no differences in DON concentrations (Smith-Spangler et al., 2012).

3.5.1.2 *T2/HT2 toxins*

In total, ten studies comparing the content of T2/HT2 toxins in organic and conventional produced cereals have been included. Oats was included in five studies, barley in three, wheat in three and rye in one (altogether 12 comparisons).

Table 24. Content of T2/HT2 toxins in cereals from organic farming relative to conventional farming: + increase; 0 no effect; - decrease. The table summarizes the results of studies that compare T2/HT2 toxin contamination (mean and/or median concentration levels and/or contamination frequencies) in the two farming systems. Some of the studies include more than one cereal species.

Effect	No of studies	References
+	1	Bakutis et al 2006 (wheat)
0	4	Kuzdralinsky et al 2013(oats); Edwards 2009a (barley); Bakutis et al 2006 (barley); Griesshaber et al 2004 (wheat)
-	6	Blajet-Kosicka et al 2014 (rye); Twaruzek et al 2013 (oats); Bernhoft et al 2010 (barley, oats); Edwards 2009b (oats); Edwards 2009c (wheat); Gottschalk et al 2007 (oats)

In a majority of the studies, organic cereals were found to have lower T2 and HT2 contamination compared to conventional cultured cereals (Table 24). Two studies in barley, one study in oats and one in wheat reported no differences in the content of T2/HT2 in cereals from the two farming systems. In one study, higher levels of T2 were found in wheat from organic farms than from conventional farms.

In a review of the occurrence of T2 and HT2 toxins in cereals in Europe, Fels-Klerx and Stratakou (2010) concluded that organically produced cereals contained lower levels than conventionally grown cereals (Fels-Klerx and Stratakou, 2010).

3.5.1.3 *Zearalenon (ZEA)*

ZEA was detected in 16 studies comparing the content in organically and conventionally produced cereals. Wheat was included in 12 of the studies, rye in three, barley in two and oats in three (altogether 20 comparisons).

Table 25. Content of zearalenon (ZEA) in cereals from organic farming relative to conventional farming: + increase; 0 no effect; - decrease. The table summarizes the results of studies that compare ZEA contamination (mean and/or median concentration levels and/or contamination frequencies) in the two farming systems. Some of the studies include more than one cereal species.

Effect	No of studies	References
+	1	(Marx et al., 1995) (wheat and rye)
0	10	(Błajet-Kosicka et al., 2014) (rye); (Twarużek et al., 2013) (oats); (Vidal et al., 2013) (wheat, oats); (Lacko-Bartosova and Kobida, 2011) (wheat); (Bernhoft et al., 2010) (oats); (Edwards, 2009c) (wheat); (Hoogenboom et al., 2008) (wheat); (Harcz et al., 2007) (wheat); (Champeil et al., 2004) (wheat); (Döll et al., 2002) (wheat)
-	5	(Meister, 2009) (rye, wheat); Bakutis et al 2006 (wheat, barley); (Pussemeier et al 2006a (wheat); Schneweis et al 2005 (wheat); (Malmauret et al. 2002) (barley)

In the majority of the studies no differences were reported in ZEA content between the two cultivation systems (Table 25).

3.5.1.4 *Nivalenol (NIV)*

NIV was detected in 9 studies comparing the content in organically and conventionally produced cereals. Wheat was included in six of the studies, barley in three and oats in four (altogether 13 comparisons).

Table 26. Content of nivalenol (NIV) in cereals from organic farming relative to conventional farming: + increase; 0 no effect; - decrease. The table summarizes the results of studies that compare NIV contamination (mean and/or median concentration levels and/or contamination frequencies) in the two farming systems. Some of the studies include more than one cereal species.

Effect	No of studies	References
+	0	
0	8	(Kuzdraliński et al., 2013) (oats); (Bernhoft et al., 2010) (oats, barley); (Mader et al., 2007) (wheat); (Perkowski et al., 2007)(wheat); (Griesshaber et al., 2004) (wheat); (Champeil et al., 2004) (wheat); (Eltun, 1996a) (barley, oats, wheat); (Malmauret et al. 2002) (barley, wheat)
-	1	(Twarużek et al., 2013) (oats)

In most of the studies no differences were reported in NIV content between the two cultivation systems (table 26).

3.5.1.5 *Ochratoxin A (OTA)*

OTA is a toxin produced during the storage of the cereals, mainly if the grains are not sufficiently dry (ie 14 % moisture or less). OTA was detected in 7 studies comparing the content in organically and conventionally produced cereals. Wheat was included in six studies, rye in four, barley in three and oats in three studies (altogether 16 comparisons). Most studies showed higher OTA content in organic than in conventional cereals.

Table 27. Content of ochratoxin A (OTA) in cereals from organic farming relative to conventional farming: + increase; 0 no effect; - decrease. The table summarizes the results of studies that compare OTA contamination (mean and/or median concentration levels and/or contamination frequencies) in the two farming systems

Effect	No of studies	References
+	6	(Vidal et al., 2013) (oats); Pussemier et al 2006b (wheat/incidence); (Czerwiecki et al., 2002a) (rye, wheat, barley); (Czerwiecki et al., 2002b) (rye, barley); (Jørgensen and Jacobsen, 2002) (rye); (Jørgensen et al., 1996) (rye)
0	5	(Kuzdraliński et al., 2013) (oats); (Vidal et al., 2013)(wheat); Pussemier et al 2006b (wheat/concentration); (Jørgensen and Jacobsen, 2002) (wheat); (Jørgensen et al., 1996) (oats, barley, wheat)
-	1	(Czerwiecki et al., 2002b) (wheat)

The difference between organic and conventional cereals is likely to be related to drying and storage conditions. It is unlikely that the use of fungicides in the field has an influence on the growth of *Penicillium* and potential OTA production after harvest. However, one cannot preclude the possibility that there might be differences between the two farming methods, which may facilitate growth of *Penicillium*, eg a greater amount of impurities in organic cereals or less uniform maturity, which mean that correct handling and drying are even more important for organic than for conventional cereals.

In a review of six studies included in a “summary effect size calculations”, Smith-Sprangler et al (2012) found no difference in risk for OTA contamination in organic wheat compared with conventional (Smith-Spangler et al., 2012).

A Polish study on the effect of lactic acid bacteria strains on the quality of silages produced from meadow sward, was conducted in organic and conventional farms (Suterska et al., 2009). No differences in the OTA content between the silages from the two farming systems were found and selected bacteria strains showed good effects in both systems.

3.5.1.6 *Other toxins in cereals (DAS, MON, aflatoxins, ergot alkaloids)*

In a Polish study in oats during 2006-2008 four times higher concentrations of diacetoxyscirpenol (DAS) were found in samples from conventional than in samples from organic farms (Kuzdraliński et al., 2013). In another Polish study (2009-2011) no differences were detected in DAS concentrations in oats from organic and conventional farming (Twarużek et al., 2013).

Bernhoft et al 2010 detected lower moniliformin (MON) in organic than in conventional wheat (Bernhoft et al., 2010).

Kuzdralinsky et al (2013) also reported lower aflatoxin levels in oat samples from organic farming one year, however, no differences were found between samples from organic and conventional farming when all samples were considered together (Kuzdraliński et al., 2013).

In a German study of ergot alkaloids (*Claviceps pupurea*) in rye grains, Lauber et al (2005) found lower concentrations of alkaloids in organically grown rye compared to conventionally grown rye (Lauber et al., 2005).

3.5.2 Other crops (fruit, berries, vegetables, pea, and flax)

Nine studies comparing the patulin content in organically and conventionally produced apples and apple products were assessed. Four studies showed higher patulin contamination in organic than in conventional products and seven studies reported no contamination differences in conventional and organic products. The difference may be due to more efficient disease control in conventional orchards, which reduces the mycotoxin producing fungi in apple fruits.

Table 28. Content of patulin in apples and apple-based products from organic farming relative to conventional farming: + increase; 0 no effect; - decrease. The table summarizes the results of studies that compare patulin contamination (mean and/or median concentration levels and/or contamination incidence) in the two farming systems (one study showed no difference in patulin incidences, but higher concentration level in organic, and one study showed different result for fresh apples and apple juices).

Effect	No of studies	References
+	4	Pique et al., 2013; Baert et al., 2006 (concentration level); Piemontese et al., 2005 (concentration level apple juices); Beretta et al., 2000
0	7	Barreira et al., 2010; Versari et al., 2007; Spadaro et al., 2007; Baert et al., 2006 (incidence); Piemontese et al., 2005 (concentration level fresh apples); Ritieni et al 2003; (Malmauret et al. 2002)
-	0	

In addition to reporting own results, Pique et al (2013) presented an update of the patulin occurrence and their risk in conventional and organic apple juices around Europe. They concluded that the incidence and levels of patulin were, in general, higher in organic than in conventional apple products.

Although patulin production is believed to occur mainly post-harvest, also factors during the growing season may influence fungal infection and mycotoxin production in apples. Post-harvest decay can be reduced by pre-harvest fungicide applications (reviewed by Jackson and Fadwa Al-Taher 2008). Further it is pointed out that patulin in apples is very sensitive and responsive to harvesting techniques, storage conditions and other processing practices that are not relevant to the farming system per se. It has been shown that, in rotten apples, the patulin spreads to unaffected parts of the fruit (Beretta et al., 2000) and it is emphasised that the quality of the fruit in the production of apple products should be strictly controlled.

In Denmark, Jensen et al (2013) analysed organic and conventional strawberries for a number of mycotoxins. No toxins were detected in mature berries from either of the cultivation system, including samples of low quality berries (Jensen et al., 2013).

In a study on occurrence of *Alternaria* toxins in flax and pea in Czech Republic in 2002-2003 (Kralova et al., 2006), higher concentrations were found in organic than in conventional samples of flax from one year. No *Alternaria* toxins were detected in pea samples.

3.5.3 Literature reviews on mycotoxins in general

Rembialkowska et al (2012) stated in their review that studies comparing the mycotoxin content in organic vs. conventional products show comparable amounts in both types of products, sometimes indicating lower content of mycotoxins in organic products (Rembiałkowska et al., 2012). Lairon (2010) concludes in a review that organic cereals contain overall similar levels of mycotoxins as conventional ones (Lairon, 2010). Another review (Frere et al., 2005) concludes that results for mycotoxin contamination in cereals are variable and inconclusive. In a review on chemical safety of conventionally and organically produced foodstuffs, Pussemier et al (2006) pointed out that it was not possible to assert that the absence of plant protection products systematically leads to a higher mycotoxin contamination. Benbrook (2006) surveyed nine studies, including food products, and concluded that mycotoxins were detected more frequently in the conventional samples compared to the organic samples. Conventional samples were found positive about 50 percent more often, compared to corresponding organic samples. However, he pointed out that the majority of the positive samples both in organic and conventional products were well below current acceptable levels. FAO (2000) stated on basis of several studies that it cannot be concluded that organic farming leads to an increased risk of mycotoxin contamination.

Basic aspects of mycotoxins in fruit and vegetables were covered in a review by (Barkai-Golan and Paster, 2008). Attention was drawn to studies reporting higher patulin contamination in organic fruits versus conventional ones, and the need for strict pre-processing control of fruits grown under organic conditions

3.5.4 Conclusion on mycotoxins

Contamination of cereals with mycotoxins is widespread. Results from comparisons of mycotoxin content in organic and conventional cereals vary among different crops and for different mycotoxins. It cannot be concluded that any of the two farming systems leads to increased mycotoxin contamination. Despite no use of fungicides, an organic system appears generally able to maintain contamination at low levels.

Most studies found no difference in DON content, and the majority of the remaining studies reported on lower levels of DON in organic then in conventional cereals.

Of the published European studies on other mycotoxoins most report on no differences between the cultivation systems because of low, often unimportant levels, in most cases far below the EU maximum acceptable levels. One exception is T-2 and HT-2 toxins, where most studies show that organically produced cereals contain lower levels than conventionally grown cereals.

Organic cereal farmers practice wider crop rotation, more ploughing, and they apply less fertilizer which gives lower plant density then on conventional farms. DON producing fungi are partly controlled by fungicides in conventional farming, while there are no approved fungicides for control of T-2 and HT-2 producing fungi. More systematic comparisons performed in field trials under scientifically controlled conditions are needed to clarify if there are differences in the risk of mycotoxin contaminations between organically and conventionally produced crops.

Occurrence of mycotoxins in organic and conventional cereal grains in Norway has not been compared in recent years after the considerable increase in DON contamination in cereals (Bernhoft et al, 2013).

3.6 Comparison of seed quality

3.6.1 Seed quality and seed regulations

High-quality seed is essential for a successful plant production and the basis for production of nutritious and healthy food and feedstuffs. A good yield and crop quality depends on the suitability of seed for planting purposes, particularly its potential for rapid emergence and uniform plant establishment (germination and vigour), freedom from weeds and seed borne diseases, and trueness of the required variety (genetic quality/cultivar purity).

Seed quality is determined by a number of conditions, such as source of seeds, location, environmental conditions during growing and maturation, infection by diseases and development of weeds during the growing season, harvesting, drying, handling, conditioning, seed treatment and storage.

The seed production and trade of seeds in Norway is regulated by Regulation 13 September 1999 No 1052 on Seeds (http://www.lovdata.no/for/sf/ld/xd-19990913-1052.html). This regulation contains production and marketing directions, and quality standards for certified seeds, including minimum requirements with regard to germination capacity and purity (seed free from weeds, other species and impurities/inert matter), and a few seed health requirements.

A prerequisite for organic farming is that seed must be produced under organic conditions for at least one generation in the case of annual crops, and for two growing seasons for biennial and perennial crops (Regulation 4 October 2005 No 1103 Forskrift om økologisk produksjon og merking av økologiske landbruksprodukter og næringsmidler http://lovdata.no/dokument/SF/forskrift/2005-10-04-1103 ; EC, 2007) Both organically and conventionally propagated seeds must meet the current requirements in Regulation 13 September 1999 No 1052 on Seeds, and therefore no seed quality differences would be expected.

3.6.2 Challenges in the production and availability of organic seed

Because of the abandoning of the use of chemicals in organic plant production, including seed production fields, there is a greater risk of contamination of the seed yield with weed seeds and seed borne diseases (van Bueren et al 2003; Marshall and Humphreys 2002; Groot et al 2004; Velema 2004). Apart from the specific tolerance levels for loose smut in barley and oat seeds (*Ustilago nuda* and *U. avenae*, respectively), ergot (*Claviceps purpurea*) in cereals and grass seeds, and stem rot (*Sclerotinia sclerotiorum*) in *Brassica* seeds, there is only a general statement in the Regulation 13 September 1999 No 1052 on Seeds, that infection level of seed borne diseases that might reduce the quality of seeds shall be as low as possible. Organic seeds might therefore be infected with other diseases than those mentioned, and still sold as certified seeds. However, since 1990 all barley seed lots and from 1997 all oats and wheat seed lots in Norway, have been routinely tested on voluntary basis for important seed borne pathogens, and when infection levels exceed certain thresholds, seed treatment is recommended (Brodal et al 1993; Brodal et al 1997), or the seed lots might not be recommended to be used for seed. Some European countries have introduced national seed health standards for organic cereal seed (Nielsen et al, 2001; Girsch and Weinhappel 2004).

Because chemical-synthetic seed treatment fungicides are not allowed in organic farming, seed borne diseases are one of the factors that limit the amount of available organic seed ((Borgen, 2004); (van Bueren et al., 2003); (Nielsen et al., 1999)). Another limiting factor is weed seed contamination above the purity standard level, referred to as one of the main challenges in certified organic herbage seed production in Finland (Niskanen 2004).

If certified organically produced seed of suitable varieties are not available according to the list of organic seed at http://www.okofro.no/ , it is possible to apply for exemption from the Regulation 4 October 2005 No 1103 Forskrift om økologisk produksjon og merking av økologiske landbruksprodukter og næringsmidler, to use conventional seed, on condition that it has not been treated with chemical-synthetic pesticides (others products than those authorized in EU regulation 889/2008). Therefore, a considerable amount of organic production is based on untreated, conventionally produced seeds (van Bueren et al., 2003).

One aspect often commented on in connection with organic seed production and quality is the lack of varieties adapted to organic conditions (Osman et al 2008; Wolfe et al 2008). In a review, van Bueren et al (2011) point out that varieties bred for conventional conditions often lack important traits required under organic farming conditions, e.g. competitiveness against weeds and resistance to seed-borne diseases, such as common bunt (*Tilletia caries*) in wheat (van Bueren et al., 2011). Also, some of the traits (e.g., semi-dwarf genes) that were introduced to address problems like cereal lodging in conventional systems were shown to have negative side-effects (reduced resistance to diseases such as *Septoria*, lower protein content, reduced size and depth of root systems, poorer nutrient-use efficiency) under organic agronomic conditions.

Döring et al (2012) reviewed the current status of the organic seed regulations within Europe and suggested focus both on regulatory, economic as well as plant breeding issues to increase the possibilities for organic seed production and reduce the gap between organic seed supply and demand. In order to promote the formal and informal organic seed sector and to improve the availability and biodiversity of organic seed and plant materials IFOAM (2011) issued their Position Paper on the Use of Organic Seed and Plant Propagation Material in Organic Agriculture.

3.6.3 Comparison organic and conventional seed quality

Seeds might be influenced by farming conditions and infected with diseases resulting in slow germination and less vigour, and contaminated with weed seeds. However, the number of peer-reviewed papers comparing quality of conventional and organic seed is limited. There are no Norwegian studies on this topic. Comparisons of seed quality from the two farming systems have had low attention due to limited availability of organic seeds, and the use of healthy and cheaper conventional seed. Some organic farmers save their own seed; however, information about the quality of farm saved seed is not available.

3.6.4 Cereals

In one of the very few studies comparing seed quality from the different farming categories, Capouchova et al (2012) in the Czech Republic, found no significant differences in the biological traits between conventional, organic and farm saved oat seed, although there was a tendency to higher germination, emergence and 1000 grain weight in conventional untreated seeds compared to organic and farm saved seeds (germination 88.3% vs 74.2%, emergence 79.1% vs 65.4% and TGW 31.9g vs 24.9g) (Capouchova et al., 2012). In a Polish study, no differences were found in the sowing value of wheat seed from organic and conventional farming systems (Panasiewicz et al., 2011). However, in a similar study with barley seeds, seeds from conventional crops showed higher germination capacity and vigour expressed in seedling growth test, seedlings growth rate test, Hiltner test and vigor index (Panasiewicz et al., 2010). In another Polish study in barley (Borowczak and Rebarz, 2008), germination was higher in seeds from organic (94.6%) than integrated (92.5%) and conventional (91.5%) cultivation. Higher proportion of the largest fraction of barley seed (diameter above 2,75 mm) was found in seed from organic and integrated system compared to conventional system.

In Sweden, L-Baeckström et al. (2006) found higher seed infection by *Drechslera tritici-repentis* in organic than in conventional wheat, whereas there was higher infection by *Stagonospora nodorum* in conventional than in organic system (L-Baeckstrom et al., 2006). Seed infection by *Fusarium* spp was in their study unaffected by cropping systems. In a German study, the conventional system did not result in lower mean infection rates of *Fusarium* spp, *Drechslera* spp. and *Stagonospora* spp. than integrated and organic production (Bahle and Leist, 1997). They found slightly higher levels of common bunt (*T. caries*) in organically produced wheat than in conventional production.

In Denmark, Kristensen (2003) found higher germination percentage and lower mean germination time in organic seeds compared to conventional seeds (Kristensen, 2003). However, seed from organic system had a higher proportion of large seeds. Proportion of "small shrivelled, brown discoloured seeds" (indicator of poor seed quality and disease occurrence) was found to be lower in wheat seeds from integrated than in wheat seeds from organic farms (Lisowicz, 1999). In barley, no differences in "small shrivelled, brown discoloured seeds" were found between integrated and organic system.

In a review, van Bueren et al (2003) reported that organic cereal seed lots are most frequently discarded because of contamination with common bunt (van Bueren et al., 2003). Other reasons reported are insufficient grading of the seeds by not excluding the smaller, usually infected ones, slow germination ability and presence of seed-borne *Fusarium* spp. and *S. nodorum.*

Many studies have been conducted on alternative seed treatments to control common bunt and other seed borne diseases in cereals, and several of these alternatives have been shown to be efficient with limited effects on germination, and thereby secure a high seed quality.

However, not much information exists on the use of these treatments in commercial organic seed production. However, during the last seasons a considerable amount of the Norwegian cereal seeds, including both conventional and organic, have been treated with moist heat/ThermoSeed (Felleskjøpet 2013). The method, developed in Sweden (Forsberg et al 2002), has shown good effect against a number of seed borne diseases.

3.6.5 Oil seed crops

In a Canadian study of pollination, measured as number of seeds per pod in oil seed fields (*Brassica napus* and *B. rapa*), higher pollination and bee abundance were measured in organic than in conventional, and herbicide-resistant, genetically modified (GM) fields (Morandin and Winston 2005). There was a strong, positive relationship between bee abundance at sampling locations and pollination. Seed set increased with greater bee abundance. The study illustrates the importance of wild bees to agricultural production and suggests that organic cultivation systems may better sustain wild bee abundance, resulting in greater seed production.

3.6.6 Grasses

Weed control and application of nitrogen at precise stages of crop development are mentioned as important challenges for the organic forage seed production (Marshall and Humphreys 2002; Falcinelli 2007). However, no peer-reviewed studies comparing quality of organically and conventionally produced seeds have benne identified.

3.6.7 Vegetables

In the review by van Bueren et al (2003) a number of seed-borne diseases in vegetables are emphasised, and most of them are considered just as severe in organic as in conventional systems. Extra attention is needed for the organic seed production of biennial crops such as *Brassica* spp, onion and carrot because the crops are exposed to various diseases during the two seasons that are needed for seed production.

Hybrid seed production is another complication. It is known that seed production of hybrids in general can be more difficult than that of open-pollinated cultivars, because of the need to synchronize flowering of both parental lines in separate rows. This can be even more challenging under organic conditions, where the plants development is less easy to control (van Bueren et al., 2003).

3.6.8 Summary / conclusions (seed quality)

It is not possible to draw a conclusion about quality differences of seed from organic and conventional production because there are only a few comparative studies available. There are no studies published on the quality of Norwegian organic and conventional seed.

One reason for the small number of comparative studies might be that certified seed, organic or conventional, must meet the same quality requirements of the seed regulation (EU regulations. Besides, the limited availability of organic seed for many plant species might be another reason for the lack of comparative studies.

Altogether only 9 papers have been identified and most of them reports on germination capacity, vigour, emergence, seed health and seed size in cereals. In most studies no differences were found in quality of seeds from organic and conventional production. However, a higher proportion of seed borne diseases was found in organic than in conventional seeds.

One paper from Canada reported higher pollination and seed set in organic oil seed crops due to higher wild bee abundance.

No papers have been found that compare the genetic/cultivar and seed lot purity, including weed contents, of organically and conventionally produced seeds.

3.6.9 Data gaps (seed quality)

More data, including studies of Norwegian seed quality, are needed to be able to assess possible quality differences between organically and conventionally produced seed.

3.7 Comparison of quality in seed potato

The potato seed production and trade in Norway is regulated by Regulation 2 July 1996 No 1447 on Seed potatoes, http://lovdata.no/dokument/SF/forskrift/1996-07-02-1447. This regulation contains production and marketing directions, and quality standards for certified potatoes, including absence of a number of quarantine pests and diseases, trueness of the required variety, and minimum requirements with regard to several viruses and tuber qualities. In addition, seed potatoes for organic production need to be produced under organic conditions for at least one generation (Regulation 4 October 2005 No 1103 Forskrift om økologisk produksjon og merking av økologiske landbruksprodukter og næringsmidler http://lovdata.no/dokument/SF/forskrift/2005-10-04-1103 ; EC, 2007) Because both organically and conventionally propagated seed potatoes must meet the current requirements in Regulation 2 July 1996 No 1447 on Seed potatoes, no seed quality differences would be expected.

Organic seed potato production in Norway is limited. At the moment there is only one grower (personal communication Ola Nøren Johansen, Food Safety Authority, 21 November 2013). As for true seed for organic production, it is possible to apply for exemption from the "Regulation 4 October 2005 No 1103 Forskrift om økologisk produksjon og merking av økologiske landbruksprodukter og næringsmidler", to use conventional seed potatoes, on similar conditions as described for true seeds.

In the literature search for studies comparing organic and conventional seed potato quality, only two peer-reviewed papers were identified. Zellner et al (2011) studied latent late blight (*Phytophthora infestans*) infection in samples from different certified European seed potato productions. The average infection rate of the seed potatoes tested was 11%. The highest occurring rate was 38%. There were no statistically significant differences between seed potatoes from organic and conventional production. In a Polish study, Goliszewski and Zarzynska (2008) found higher infection with potato leaf roll virus in potatoes from organic than in potatoes from integrated plantations. Also higher number of aphids was found in organic seed potato plantations. Infection with virus Y was lower in organic potatoes and the level of virus M was similar in both systems.

Data gaps

Very few Norwegian studies have compared organic and conventional plant production. Therefore, the evaluation is mainly based on field experiments in other countries of Europe and North America. There is a need for Norwegian field experiments to elucidate possible yield and quality differences between the harvested crops from organic and conventional plant production. Norway is on the northern frontier for commercial plant production with short growing season, low summer temperature and in some districts precipitation above the optimum for crops.

Uncertainties

The shortage of Norwegian studies comparing organic and conventional plant production is the main reason for uncertainties in the evaluations. The evaluations of nutrient content, plant health and harmful substances are mainly based on research under soil, climatic and agronomic conditions different from those that Norwegian agriculture experiences. Differences in cultivation practises and varieties grown add to the uncertainties.

Conclusion

Plant health

Most studies conclude that crop losses due to plant diseases, plant pests and weeds are higher in organic than in conventional production. The most probable explanation for these differences is that the control methods available to organic farmers are less efficient than those used in conventional farming.

Plant pests

Due to the relatively few published studies it is difficult to draw a general conclusion on the effect of organic farming vs. conventional farming on crop pests. Investigations of such effects on the pests' predators and parasitoids are more numerous, and for these groups and for biodiversity in general there is a tendency towards a positive effect of organic farming on species richness and abundance. Such a conclusion is also supported by other reviews, although some of them emphasize that the heterogeneity of the landscape surrounding the agricultural fields and farms are essential.

Pollinating insects

Insect pollinators represent an additional ecosystem service in agricultural landscapes. All of totally the 13 studies of pollinating insects in agricultural landscapes investigating pollination success, species richness or abundance, showed a positive response of organic vs. conventional farming. Higher heterogeneity of landscapes and absence of pesticides in organic farming are the most likely reasons for the difference.

Plant parasitic nematodes

There is no clear pattern emerging on the prevalence of nematode feeding groups in organic compared to conventional farming systems. The crop plants may be more important for the nematode community than management system as such. Since robust data on the effect of the management system on the abundance of species of plant parasitic nematodes and their damage is lacking, it is impossible to make statements on the role of organic farming in increasing or decreasing nematode damage.

Cereal diseases

There are different results from studies on cereal diseases in organic and conventional cultivation. Powdery mildew incidence seems to be lower in organic production and for other leaf diseases of cereals there are no consistent differences in disease incidence between the cultivation systems. Two studies reported on more root rot in organic than in conventional cereals and two found no difference. Two studies found less *Fusarium* head blight in organic than in conventional cereals, while two studies reported on no difference between the cultivation systems.

Potato diseases

Late blight is so severe on susceptible potato cultivars that only resistant cultivars can be grown organically in climate with annual late blight epidemics. No potato cultivar is completely resistant. The limited number of comparative studies on late blight and other potato diseases does not provide sufficient data to conclude that there are differences between the cultivation systems.

Apple diseases

Apple scab is the most important apple disease in temperate climate. Both in organic and integrated/ conventional cultivation control of this disease require the attention of the growers from bud break to harvest. The disease is more severe in organic production, since less efficient control methods are available. Planting resistant varieties is the most reliable method for apple scab control in organic orchards. For other apple diseases there are too few comparative studies to conclude that there are any differences in disease incidence between the cultivation systems.

Strawberry diseases

Few comparative studies of strawberry diseases in organic and conventional cultivation have been published. Grey mould is a major challenge for both organic and conventional growers. With few effective control methods available the yield losses from grey mould are larger in organic than in conventional cultivation. For other strawberry diseases there are too few comparative studies to conclude that the cultivation system will influence the disease incidence.

Field vegetable diseases

The few comparative studies on carrot and onion diseases in different cultivation systems do not provide sufficient data to conclude that there are differences in disease incidence between organic and conventional field vegetables.

Weeds

Most studies conclude that organic farming increases weed species richness. The densities of summer annual and biennial weed species are higher on organic than on conventional farms, and weed density and biomass on organic farms commonly exceed the level where the estimated benefit covers the cost of treatment (economic threshold). The most probable explanation for these differences is that the control methods available to organic farmers are less efficient than those used in conventional farming. Another reason is that on the organic plots no direct weed control measures were carried out in many studies. Perennial weed species, especially the subgroup creeping perennial weed species is another problem in organic farming.

Some studies conclude that proper use of weed harrowing in cereals may avoid yield losses caused by competition from annual weed species in organic farming. To optimize measures for non-chemical control of perennial weeds, knowledge of weed biology is crucial for determining the best method and timing of the operations. To successfully control both annual and perennial weeds in organic farming a variety of both preventive and direct measures must be included.

The crop cultivars developed before the advent of modern, high-input agriculture may be better suited to lower soil nutrients levels and elevated weed competition than the cultivars developed for conventional agriculture. Better crop rotation increases weed species richness in organic farming, while higher nitrogen levels in conventional farming reduces weed richness. Development of methods for improved weed control methods for organic farming has high priority.

Nutrients and bioactive substances

In general, there are small differences in content of nutrients, secondary plant metabolites, and other constituents in plants, except for organic fruit and berries were higher levels of dry matter, ascorbic acid and antioxidant activity have been found. In conventionally grown wheat there are commonly higher levels of protein than in organically grown wheat.

Large variation in nutrient content was found for both systems. However, some differences or trends could be found across plant products, and which can be biologically plausible due to differences of the systems. Higher contents of dry matter in organic compared to conventional products were found in many of the studies on potatoes, fruits and berries, and in some cases also for vegetables. Higher contents of nitrogen containing compounds have been found in conventional plant products compared to organic. In cereals, most studies reported higher protein contents in conventional production. In potato as well as for some leaf and root vegetables, higher nitrate contents in conventional products have been shown in some studies, whereas others found no differences. Ascorbic acid is analysed in many of the studies of fruits, berries and potato. Variable results are found but the majority of the studies report either no differences or higher average contents in the organic products.

Nutrients and bioactive substances in potato

In all but one of the research publications dry matter content is higher in organic than in integrated and conventional potato. Higher nutrient levels in the soil support rapid growth of the potato tuber at the expense of dry matter and starch content in conventional farming. Also, most papers report on higher starch content in organic than in conventional potato, but there are also studies that find no difference in starch content between the cultivation systems. Cultivation system does not influence the vitamin C content in most of the cited research publications. There are no differences in content of macro- and micronutrients between organic and integrated/conventional potato.

In some studies the level of the natural toxins, glycoalkaloids, are higher in organic than in conventional potato. In most studies the nitrate content is higher in conventional than in organic potato due to higher soil nitrogen availability in conventional then in organic farming.

Nutrients and bioactive substances in fruit

Organic production seems to have positive effect of several of the quality traits analysed, especially firmness, dry matter, ascorbic acid, antioxidant activity and phenolic compounds (apples). Nevertheless, the results do also show a large variation between the different production methods, which could be due to the many variables in the trials (e.g. years, with various climatic conditions, genetic variations). Long term studies with fewer variables would probably give a better picture on the effect of production systems on nutrients in fruits. Only one study on nutrients in plum and one on nutrients in cherry were found. This is not sufficient to draw any conclusion.

Nutrients and bioactive substances in berries

Results from the included studies can be interpreted as positive for organic production on quality traits and nutrients in berries, e.g. antioxidant activity, anthocyanins, ellagic acid, ascorbic acid, soluble solids and some minerals. Nevertheless, some of the studies showed no effect of production system, or even lower values in organically than in conventionally produced berries.

Nutrients and bioactive substances in vegetables

Reviewing the selected studies on the effect of different production systems on nutrients in vegetables resulted in various, and less clear results. Conventional and organic production systems seem to have both positive and no effect on many of the nutrients analyzed. Vegetables grown in organic production systems have higher nutrient content in some studies, while in other studies there is no effect of the growing system on nutrients. Therefore, it is not possible to draw a clear conclusion on the effect of production system on nutrients in vegetables.

Nutrients in cereals

There are convincing data to conclude that the protein content is commonly lower in organically produced wheat compared to conventional wheat. Similar trends are found also for oats and barley, but the number of studies is low. High protein content is important for the baking quality of wheat flour.

For other nutrients, the literature is too limited for any sound conclusions to be drawn.

Nutrients in grasses

Because of the low number of comparative studies, sound conclusions cannot be made on differences in nutrient contents between organic and conventional leys/forage.

Environmental chemical contaminants

The source of organic chemical contaminants in soil is probably more related to sources that are not influenced by the differences in agricultural practises between organic and conventional farming, such as prior use of the soil, nearby industry or roads, possible contamination of irrigation water, or airborne pollution, even though manure may also be a source. The uptake of most organic chemical contaminants from the soil is very low or negligible. A large difference in levels of organic chemical contaminants in plant food from organic and conventional grown products is therefore not to be expected.

The occurrence of metals in the soil may both depend on the agricultural factors such as fertilizers and non-agricultural factors such as geology, industrial waste, air pollution etc. The levels of metals, including heavy metals, in plants are known to depend on both crop plant, soil concentrations of the metals, chemical forms, and a range of soil parameters such as organic matters, pH, humidity, temperature etc. Some of these soil parameters, such as pH, and organic matter content are probably affected by farming practices over time.

Due to high human consumption, cereals and vegetables are important sources for dietary intake of heavy metals.

Mycotoxins

Results from comparison of mycotoxin contamination in organic and conventional cereals are variable. Most studies found no difference in DON content and the majority of the remaining studies reported on lower levels of DON in organic then in conventional cereals. Most studies showed that organically produced cereals contained lower levels of T-2 and HT-2 toxin than conventionally grown cereals. Organic cereal farmers practice wider crop rotation, more ploughing, and they apply less fertilizer which gives lower plant density then on conventional farms. DON producing fungi are partly controlled by fungicides in conventional farming, while there are no approved fungicides for control of T-2 and HT-2 producing fungi.

Some studies showed higher mycotoxin contamination in organic than in conventional apple products, while other studies reported no differences in similar contamination. The difference may be due to more efficient disease control in conventional orchards, which reduces the mycotoxin producing fungi in apple fruits.

Seed and seed potato quality

It is not possible to draw a conclusion about quality differences of seed from organic and conventional production because there are only a few comparative studies available. There are no studies published on the quality of Norwegian organic and conventional seed. In most international studies no differences were reported in seed quality from organic and conventional production. However, a higher proportion of seed borne diseases was found in organic than in conventional seeds.

In the search for studies comparing organic and conventional seed potato quality, only two peer-reviewed papers were identified, and it is not possible to conclude on possible differences in seed potato quality between the cultivation systems.

References

ABREU, P., RELVA, A., MATTHEW, S., GOMES, Z. & MORAIS, Z. 2007. High-performance liquid chromatographic determination of glycoalkaloids in potatoes from conventional, integrated, and organic crop systems. *Food control,* 18**,** 40-44.

ADAMCZYK, M. J., KOSTYRA, E., WASIAK-ZYS, G., HALLMANN, E., BATORSKA, D. & REMBIALKOWSKA, E. 2010. Sensory and instrumental analysis of selected cultivars of apples from organic and conventional production. *In:* FORDERGEMEINSCHAFT OKOLOGISCHER OBSTBAU E, V. (ed.). Weinsberg: Fordergemeinschaft Okologischer Obstbau e V (FOKO).

ADLER, S. & STEINSHAMN, H. 2010. Forage botanical and chemical composition on dairy farms with different grassland systems and production systems. (Grassland Science in Europe, Volume 15). *In:* SCHNYDER, H., ISSELSTEIN, J., TAUBE, F., AUERSWALD, K., SCHELLBERG, J., WACHENDORF, M., HERRMANN, A., GIERUS, M., WRAGE, N. & HOPKINS, A. (eds.). Duderstadt: Mecke Druck und Verlag.

ADLER, S. A., JENSEN, S., GOVASMARK, E. & STEINSHAMN, H. 2013. Effect of short-term versus long-term grassland management and seasonal variation in organic and conventional dairy farming on the composition of bulk tank milk. *Journal of dairy science,* 96**,** 5793-5810.

ADOLFSSON, E. 1996. Weed control in Swedish agriculture in the early 20th century-analysis of a contemporary inquiry. *Svensk Botanisk Tidskrift,* 90.

AGHA, J. M. & PALLUTT, B. 2006. Weed population dynamics in integrated and organic cereal cropping systems. *Journal of Plant Diseases and Protection***,** 385-392.

ALBRECHT, H. 2005. Development of arable weed seedbanks during the 6 years after the change from conventional to organic farming. *Weed Research,* 45**,** 339-350.

ALVAREZ, T., FRAMPTON, G. K. & GOULSON, D. 2001. Epigeic Collembola in winter wheat under organic, integrated and conventional farm management regimes. (Special issue: A tribute to Hamish Sturrock). *Agriculture, Ecosystems & Environment,* 83**,** 95-110.

ALYOKHIN, A. & ATLIHAN, R. 2005. Reduced fitness of the Colorado potato beetle (Coleoptera : Chrysomelidae) on potato plants grown in manure-amended soil. *Environmental Entomology,* 34**,** 963-968.

ANDERSEN, A. & ELTUN, R. 2000. Long-term developments in the carabid and staphylinid (Col., CArabidae and Staphylinidae) fauna during conversion from conventional to bilogivcal farming. *Journal of Applied Entomology,* 124**,** 51-56.

ANDERSSON, G. K. S., RUNDLOF, M. & SMITH, H. G. 2012. Organic Farming Improves Pollination Success in Strawberries. *Plos One,* 7.

ANDERSSON, P.-A. 2007. Skräppa–ett växande problem i ekologisk odling. *Slutrapport från försöksserien L5-280, Hushållningssällskapet, Jönköping*.

ANDERSSON, S. 1967. Investigations on the occurrence and behaviour of Ditylenchus destructor in Sweden. *Nematologica,* 13**,** 406-416.

ANDREWS, P. K., FELLMAN, J. K., GLOVER, J. D. & REGANOLD, J. P. 2001. Soil and plant mineral nutrition and fruit quality under organic, conventional, and integrated apple production systems in Washington State, USA. *Acta Horticulturae,* 564**,** 291-298.

ANNETT, L. E., SPANER, D. & WISMER, W. V. 2007. Sensory profiles of bread made from paired samples of organic and conventionally grown wheat grain. *Journal of Food Science,* 72**,** S254-S260.

ANON. 2008. Skadedyr og skadedyrkontroll i jordbær, Plantevern og plantehelse i økologisk landbruk. *In:* RØEN, D., BRANDSÆTER, L-O., BIRKENES, S.M., JAARSTAD, G., NES, A., TRANDEM, N. & STENSVAND, A. (ed.) *Bioforsk FOKUS.*

ANTTONEN, M. J. & KARJALAINEN, R. O. 2006. High-performance liquid chromatography analysis of black currant (Ribes nigrum L.) fruit phenolics grown either conventionally or organically. *Journal of Agricultural and Food Chemistry,* 54**,** 7530-7538.

ARMENGOT, L., JOSE-MARIA, L., CHAMORRO, L. & SANS, F. X. 2013. Weed harrowing in organically grown cereal crops avoids yield losses without reducing weed diversity. *Agronomy for Sustainable Development,* 33**,** 405-411.

ARMENGOT, L., SANS, F. X., FISCHER, C., FLOHRE, A., JOSE-MARIA, L., TSCHARNTKE, T. & THIES, C. 2012. The ss-diversity of arable weed communities on organic and conventional cereal farms in two contrasting regions. *Applied Vegetation Science,* 15**,** 571-579.

ARNCKEN, C. M., MADER, P., MAYER, J. & WEIBEL, F. P. 2012. Sensory, yield and quality differences between organically and conventionally grown winter wheat. *Journal of the Science of Food and Agriculture,* 92**,** 2819-2825.

BAERT, K., MEULENAER, B. D., KAMALA, A., KASASE, C. & DEVLIEGHERE, F. 2006. Occurrence of patulin in organic, conventional, and handcrafted apple juices marketed in Belgium. *Journal of Food Protection,* 69**,** 1371-1378.

BAHLE, F. & LEIST, N. 1997. Influence of conventional, integrated and ecological agriculture and different cultivation techniques on the infection of winter wheat with seedborne fungi. *Gesunde Pflanzen,* 49**,** 220-225.

BAIAMONTE, I., RAFFO, A., NARDO, N., PAOLETTI, F., BONOLI, M., BARUZZI, G. & FAEDI, W. 2010. Anthocyanin content of strawberries (Fragaria ananassa) grown in either organic or integrated production systems. *Acta Horticulturae,* 873**,** 303-308.

BAKUTIS, B., BALIUKONIENE, V. & LUGAUSKAS, A. 2006. Factors predetermining the abundance of fungi and mycotoxins in grain from organic and conventional farms. *Ekologija,* 3**,** 122-127.

BALAS, J. 2003. Organic & integrated grown pears - aspects of postharvest behaviour. *Acta Horticulturae,* 599**,** 653-656.

BANFIELD-ZANIN, J. A., ROSSITER, J. T., WRIGHT, D. J., LEATHER, S. R. & STALEY, J. T. 2012. Predator mortality depends on whether its prey feeds on organic or conventionally fertilised plants. *Biological Control,* 63**,** 56-61.

BARBAS, P. & SAWICKA, B. 2010. Changes of weed infestation in potato under and integrated ecological and production systems. *Progress in Plant Protection,* 50**,** 1361-1365.

BARKAI-GOLAN, R. & PASTER, N. 2008. Mouldy fruits and vegetables as a source of mycotoxins: part 1. *World Mycotoxin Journal,* 1**,** 147-159.

BARREIRA, M. J., ALVITO, P. C. & ALMEIDA, C. M. M. 2010. Occurrence of patulin in apple-based-foods in Portugal. *Food Chemistry,* 121**,** 653-658.

BAT, K. B., VIDRIH, R., NECEMER, M., VODOPIVEC, B. M., MULIC, I., KUMP, P. & OGRINC, N. 2012. Characterization of Slovenian apples with respect to their botanical and geographical origin and agricultural production practice. *Food Technology and Biotechnology,* 50**,** 107-116.

BATARY, P., HOLZSCHUH, A., ORCI, K. M., SAMU, F. & TSCHARNTKE, T. 2012. Responses of plant, insect and spider biodiversity to local and landscape scale management intensity in cereal crops and grasslands. *Agriculture Ecosystems & Environment,* 146**,** 130-136.

BATURO, A. 2007. Effect of organic system on spring barley stem base health in comparison with integrated and conventional farming. *Journal of Plant Protection Research,* 47**,** 167-178.

BAVEC, M., TURINEK, M., MLAKAR, S. G., MIKOLA, N. & BAVEC, F. 2012. Some internal quality properties of white cabbage from different farming systems. *Acta Horticulturae,* 933**,** 577-583.

BELAIR, G. & BENOIT, D. 1996. Host suitability of 32 common weeds to Meloidogyne hapla in organic soils of southwestern Quebec. *Journal of nematology,* 28**,** 643.

BÉLAIR, G., DAUPHINAIS, N., BENOIT, D. & FOURNIER, Y. 2007. Reproduction of Pratylenchus penetrans on 24 common weeds in potato fields in Quebec. *Journal of nematology,* 39**,** 321.

BENDER, I., ESS, M., MATT, D., MOOR, U., TONUTARE, T. & LUIK, A. 2009. Quality of organic and conventional carrots. *Agronomy Research***,** 572-577.

BENDER, I. & INGVER, A. 2012. The influence of production methods on yield and quality of carrots and swedes. *Acta Horticulturae,* 960**,** 293-298.

BENBROOK, C. M. 2006. Breaking the mold–impacts of organic and conventional farming systems on mycotoxins in food and livestock feed. *State of Science Review, The Organic Center*, 58 pp. **http://organic-center.org/reportfiles/MycotoxinReport.pdf**

BENGTSSON, J., AHNSTRÖM, J. & WEIBULL, A. C. 2005. The effects of organic agriculture on biodiversity and abundance: a meta-analysis. *Journal of applied ecology,* 42**,** 261-269.

BERETTA, B., GAIASCHI, A., GALLI, C. L. & RESTANI, P. 2000. Patulin in apple-based foods: occurrence and safety evaluation. *Food Additives & Contaminants,* 17**,** 399-406.

BERKELMANS, R., FERRIS, H., TENUTA, M. & BRUGGEN, A. H. C. V. 2003. Effects of long-term crop management on nematode trophic levels other than plant feeders disappear after 1 year of disruptive soil management. *Applied Soil Ecology,* 23**,** 223-235.

BERLETH, M., BACKES, F. & KRAMER, J. 1998. Mould spectrum and mycotoxins (deoxynivalenol and ochratoxin A) in grain samples from ecological and integrated cultivated sites. *Agribiological Research,* 51**,** 369-376.

BERNHOFT, A., CLASEN, P. E., KRISTOFFERSEN, A. B. & TORP, M. 2010. Less Fusarium infestation and mycotoxin contamination in organic than in conventional cereals. *Food Additives and Contaminants A,* 27**,** 842-852.

BERNHOFT, A. , ERIKSEN, G.S., SUNDHEIM, L., BERNTSSEN, M., BRANTSÆTER A.L., BRODAL, G., FÆSTE, C.K., HOFGAARD, I.S., RAFOSS, T., SIVERTSEN, T., TRONSMO, A.M. 2013. Risk assessment of mycotoxins in cereal grain in Norway. Opinion of the Scientific Steering Committee of the Norwegian Scientific Committee for Food Safety. *VKM report.* Norwegian Scientific Committee for Food Safety, Oslo, Norway.

BERTAZZA, G., CRISTOFERI, G. & BIGNAMI, C. 2010. Fruit composition and quality of organically and conventionally grown apple, apricot and pear in the Veneto region (Northern Italy). *Acta Horticulturae,* 873**,** 309-316.

BERTSCHINGER, L., MOURON, P., DOLEGA, E., HOHN, H., HOLLIGER, E., HUSISTEIN, A., SCHMID, A., SIEGFRIED, W., WIDMER, A., ZURCHER, M. & WEIBEL, F. 2004. Ecological apple production: a comparison of organic and integrated apple-growing. *Acta Horticulturae,* 638**,** 321-332.

BIANCHI, F., BOOIJ, C. & TSCHARNTKE, T. 2006. Sustainable pest regulation in agricultural landscapes: a review on landscape composition, biodiversity and natural

pest control. *Proceedings of the Royal Society B: Biological Sciences,* 273**,** 1715-1727.
BIMOVA, P. & POKLUDA, R. 2009. Impact of organic fertilizers on total antioxidant capacity in head cabbage.
BIRKHOFER, K., BEZEMER, T. M., BLOEM, J., BONKOWSKI, M., CHRISTENSEN, S., DUBOIS, D., EKELUND, F., FLIESSBACH, A., GUNST, L., HEDLUND, K., MADER, P., MIKOLA, J., ROBIN, C., SETALA, H., TATIN-FROUX, F., PUTTEN, W. H. V. D. & SCHEU, S. 2008a. Long-term organic farming fosters below and aboveground biota: implications for soil quality, biological control and productivity. *Soil Biology & Biochemistry,* 40**,** 2297-2308.
BIRKHOFER, K., FLIESSBACH, A., WISE, D. H. & SCHEU, S. 2008b. Generalist predators in organically and conventionally managed grass-clover fields: implications for conservation biological control. *Annals of Applied Biology,* 153**,** 271-280.
BIRKHOFER, K., FLIESSBACH, A., WISE, D. H. & SCHEU, S. 2011. Arthropod food webs in organic and conventional wheat farming systems of an agricultural long-term experiment: a stable isotope approach. *Agricultural and Forest Entomology,* 13**,** 197-204.
BIRZELE, B., MEIER, A., HINDORF, H., KRAMER, J. & DEHNE, H. W. 2002. Epidemiology of Fusarium infection and deoxynivalenol content in winter wheat in the Rhineland, Germany. *European Journal of Plant Pathology,* 108**,** 667-673.
BŁAJET-KOSICKA, A., TWARUŻEK, M., KOSICKI, R., SIBIOROWSKA, E. & GRAJEWSKI, J. 2014. Co-occurrence and evaluation of mycotoxins in organic and conventional rye grain and products. *Food Control,* 38**,** 61-66.
BOND, W. 2002. *Non-chemical weed management*, Blackwell Science, Oxford, UK.
BOOIJ, C. J. H. & NOORLANDER, J. 1992. FARMING SYSTEMS AND INSECT PREDATORS. *Agriculture Ecosystems & Environment,* 40**,** 125-135.
BORGEN, A. 2004. Organic seed treatment to control common bunt (Tilletia tritici) in wheat. *Seed Testing International,* 128**,** 12-13.
BOROVINOVA, M., PETROVA, V. & MANEVA, S. 2012. Effect of Different Growing Systems of Apple on Trunk and Branch Diseases and Pests. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca,* 40**,** 159-162.
BOROWCZAK, F. & REBARZ, K. 2008. Influence of irrigation and cultivation system on the yielding components and grain sowing value of spring barley. *Journal of Research and Applications in Agricultural Engineering,* 53**,** 27-31.
BOTREL, N., RESENDE, F. V., LEITE, B. S. F., NASSUR, R. C. M. R. & BOAS, E. V. B. V. 2012. Quality of Italian tomato fruit from organic and conventional production systems and stored at two temperatures. *Acta Horticulturae,* 934.
BRANDSÆTER, L., FOGELFORS, H., FYKSE, H., GRAGLIA, E., JENSEN, R., MELANDER, B., SALONEN, J. & VANHALA, P. 2010. Seasonal restrictions of bud growth on rhizomes of Elymus repens and roots of Cirsium arvense and Sonchus arvensis. *Weed Res,* 50**,** 102-109.
BRANDSÆTER, L. O., BAKKEN, A. K., MANGERUD, K., RILEY, H., ELTUN, R. & FYKSE, H. 2011. Effects of tractor weight, wheel placement and depth of ploughing on the infestation of perennial weeds in organically farmed cereals. *European Journal of Agronomy,* 34**,** 239-246.
BRANDSÆTER, L. O., MANGERUD, K. & RASMUSSEN, J. 2012. Interactions between pre-and post-emergence weed harrowing in spring cereals. *Weed Research,* 52**,** 338-347.
BRESSY, F. C., BRITO, G. B., BARBOSA, I. S., TEIXEIRA, L. S. G. & KORN, M. G. A. 2013. Determination of trace element concentrations in tomato samples at different

stages of maturation by ICP OES and ICP-MS following microwave-assisted digestion. *Microchemical Journal,* 109**,** 145-149.

BRIAR, S. S., GREWAL, P. S., SOMASEKHAR, N., STINNER, D. & MILLER, S. A. 2007. Soil nematode community, organic matter, microbial biomass and nitrogen dynamics in field plots transitioning from conventional to organic management. *Applied Soil Ecology,* 37**,** 256-266.

BRIVIBA, K., STRACKE, B. A., RUFER, C. E., WATZL, B., WEIBEL, F. P. & BUB, A. 2007. Effect of consumption of organically and conventionally produced apples on antioxidant activity and DNA damage in humans. *Journal of Agricultural and Food Chemistry,* 55**,** 7716-7721.

BROCIC, Z., MILOSEVIC, D., MACAK, M. & TYR, S. 2008. The influence of an organic and conventional systems on chemical composition of potato tubers. *Cereal Research Communications; 2008,* 5**,** 679-682.

BRODAL, G. 1993. Fungicide treatment of cereal seeds according to need in the Nordic countries. Proceedings Crop Protection in Northern Britain 1993, Dundee University 23-25 March 1993, *The Association for Crop Protection in Northern Britain*, pp 7-16.

BRODAL, G. RØSOK BYE, H., SKUTERUD, H. 1997. Report from the project "Inoculum thresholds for cereal seed borne pathogens", Norwegian Agricultural Inspection Service, 16 pp +18 pp appendixes.

BØRRESEN, T. & NJØS, A. 1994. The effect of ploughing depth and seedbed preparation on crop yields, weed infestation and soil properties from 1940 to 1990 on a loam soil in south eastern Norway. *Soil and Tillage Research,* 32**,** 21-39.

CAPOUCHOVA, I., KONVALINA, P., HONSOVA, H., STEHNO, Z. & CHALOUPSKY, R. 2012. Influence of seed's biological traits of oat on next seed generation in organic farming. *Journal of Food, Agriculture & Environment,* 10**,** 551-555.

CARBONARO, M., MATTERA, M., NICOLI, S., BERGAMO, P. & CAPPELLONI, M. 2002. Modulation of antioxidant compounds in organic vs conventional fruit (peach, Prunus persica L., and pear, Pyrus communis L.). *Journal of Agricultural and Food Chemistry,* 50**,** 5458-5462.

CARIS-VEYRAT, C., AMIOT, M. J., TYSSANDIER, V., GRASSELLY, D., BURET, M., MIKOLAJCZAK, M., GUILLAND, J. C., BOUTELOUP-DEMANGE, C. & BOREL, P. 2004. Influence of organic versus conventional agricultural practice on the antioxidant microconstituent content of tomatoes and derived purees; consequences on antioxidant plasma status in humans. *Journal of Agricultural and Food Chemistry,* 52**,** 6503-6509.

CAYUELA, J. A., VIDUEIRA, J. M., ALBI, M. A. & GUTIERREZ, F. 1997. Influence of the ecological cultivation of strawberries (Fragaria x Ananassa Cv. Chandler) on the quality of the fruit and on their capacity for conservation. *Journal of Agricultural and Food Chemistry,* 45**,** 1736-1740.

CESEVICIENE, J., SLEPETIENE, A., LEISTRUMAITE, A., RUZGAS, V. & SLEPETYS, J. 2012. Effects of organic and conventional production systems and cultivars on the technological properties of winter wheat. *Journal of the Science of Food and Agriculture,* 92**,** 2811-2818.

CHAMPEIL, A., FOURBET, J. F., DORE, T. & ROSSIGNOL, L. 2004. Influence of cropping system on Fusarium head blight and mycotoxin levels in winter wheat. *Crop Protection,* 23**,** 531-537.

CHASSY, A. W., BUI, L., RENAUD, E. N. C., VAN HORN, M. & MITCHELL, A. E. 2006. Three-year comparison of the content of antioxidant microconstituents and several quality characteristics in organic and conventionally managed tomatoes and bell peppers. *Journal of Agricultural and Food Chemistry,* 54**,** 8244-8252.

CIOLEK, A., MAKARSKA, E., WESOLOWSKI, M. & CIERPIALA, R. 2012. Content of selected nutrients in wheat, barley and oat grain from organic and conventional farming. *Journal of Elementology,* 17**,** 181-189.

CLARK, M. S. 1999. Ground beetle abundance and community composition in conventional and organic tomato systems of California's Central Valley. *Applied Soil Ecology,* 11**,** 199-206.

CLOUGH, Y., HOLZSCHUH, A., GABRIEL, D., PURTAUF, T., KLEIJN, D., KRUESS, A., STEFFAN-DEWENTER, I. & TSCHARNTKE, T. 2007a. Alpha and beta diversity of arthropods and plants in organically and conventionally managed wheat fields. *Journal of Applied Ecology,* 44**,** 804-812.

CLOUGH, Y., KRUESS, A., KLEIJN, D. & TSCHARNTKE, T. 2005. Spider diversity in cereal fields: comparing factors at local, landscape and regional scales. *Journal of Biogeography,* 32**,** 2007-2014.

CLOUGH, Y., KRUESS, A. & TSCHARNTKE, T. 2007b. Local and landscape factors in differently managed arable fields affect the insect herbivore community of a non-crop plant species. *Journal of Applied Ecology,* 44**,** 22-28.

CLOUGH, Y., KRUESS, A. & TSCHARNTKE, T. 2007c. Organic versus conventional arable farming systems: functional grouping helps understand staphylinid response. *Agriculture, Ecosystems & Environment,* 118**,** 285-290.

COLL, P., LE CADRE, E. & VILLENAVE, C. 2012. How are nematode communities affected during a conversion from conventional to organic farming in southern French vineyards? *Nematology,* 14**,** 665-676.

COLLA, G., MITCHELL, J. P., POUDEL, D. D. & TEMPLE, S. R. 2002. Changes of tomato yield and fruit elemental composition in conventional, low input, and organic systems. *Journal of sustainable agriculture,* 20**,** 53-67.

COOPER, J., SANDERSON, R., CAKMAK, I., OZTURK, L., SHOTTON, P., CARMICHAEL, A., HAGHIGHI, R. S., TETARD-JONES, C., VOLAKAKIS, N., EYRE, M. & LEIFERT, C. 2011. Effect of organic and conventional crop rotation, fertilization, and crop protection practices on metal contents in wheat (Triticum aestivum). *Journal of Agricultural and Food Chemistry,* 59**,** 4715-4724.

COOPER, J. M., SCHMIDT, C. S., LUECK, L., SHOTTON, P. N., TURNBULL, C. & LEIFERT, C. 2007. Effect of organic, low-input and conventional production systems on yield and diseases in winter barley. *In:* NIGGLI, U., LEIFERT, C., ALFOLDI, T., LUCK, L. & WILLER, H. (eds.). Frick: Research Institute of Organic Agriculture (FiBL).

CRECENTE-CAMPO, J., NUNES-DAMACENO, M., ROMERO-RODRIGUEZ, M. A. & VAZQUEZ-ODERIZ, M. L. 2012. Color, anthocyanin pigment, ascorbic acid and total phenolic compound determination in organic versus conventional strawberries (Fragaria x ananassa Duch, cv Selva). *Journal of Food Composition and Analysis,* 28**,** 23-30.

CROWDER, D. W., NORTHFIELD, T. D., STRAND, M. R. & SNYDER, W. E. 2010. Organic agriculture promotes evenness and natural pest control. *Nature,* 466**,** 109-12.

CZERWIECKI, L., CZAJKOWSKA, D. & WITKOWSKA-GWIAZDOWSKA, A. 2002a. On ochratoxin A and fungal flora in Polish cereals from conventional and ecological farms. Part 1: Occurrence of ochratoxin A and fungi in cereals in 1997. *Food Additives and Contaminants,* 19**,** 470-477.

CZERWIECKI, L., CZAJKOWSKA, D. & WITKOWSKA-GWIAZDOWSKA, A. 2002b. On ochratoxin A and fungal flora in Polish cereals from conventional and ecological farms. Part 2: Occurrence of ochratoxin A and fungi in cereals in 1998. *Food Additives and Contaminants,* 19**,** 1051-1057.

D'EVOLI, L., TAROZZI, A., HRELIA, P., LUCARINI, M., COCCHIOLA, M., GABRIELLI, P., FRANCO, F., MORRONI, F., CANTELLI-FORTI, G. & LOMBARDI-BOCCIA, G. 2010. Influence of cultivation system on bioactive molecules synthesis in strawberries: spin-off on antioxidant and antiproliferative activity. *Journal of Food Science,* 75**,** C94-C99.

DAS, R., THAPA, U., MANDAL, A. R., LYNGDOH, Y. A. & DEBNATH, S. 2013. Effect of different levels of organic manures as a source of supplement to nitrogenous fertilizer on growth, yield and quality of Sprouting broccoli (Brassica oleracea L. var Italica Plenk). *Environment and Ecology,* 31**,** 334-337.

DAVIS, A. S., RENNER, K. A. & GROSS, K. L. 2005. Weed seedbank and community shifts in a long-term cropping systems experiment. *Weed Science,* 53**,** 296-306.

DEN HOLLANDER, N., BASTIAANS, L. & KROPFF, M. 2007. Clover as a cover crop for weed suppression in an intercropping design: II. Competitive ability of several clover species. *European journal of Agronomy,* 26**,** 104-112.

DIEKOTTER, T., WAMSER, S., WOLTERS, V. & BIRKHOFER, K. 2010. Landscape and management effects on structure and function of soil arthropod communities in winter wheat. *Agriculture Ecosystems & Environment,* 137**,** 108-112.

DOLL, S., VALENTA, H., DANICKE, S. & FLACHOWSKY, G. 2002. Fusarium mycotoxins in conventionally and organically grown grain from Thuringia/Germany. *Landbauforschung Volkenrode,* 52**,** 91-96.

DOMAGALA-SWIATKIEWICZ, I. & GASTOL, M. 2012. Comparative study on mineral content of organic and conventional carrot, celery and red beet juices. *Acta Scientiarum Polonorum Hortorum Cultus,* 11**,** 173-183.

DORNER, Z., NEMETH, I., BLASKO, D. & FARKAS, A. 2004. Effect of extensive farming on weed composition in cereals in Hungary. *Zeitschrift Fur Pflanzenkrankheiten Und Pflanzenschutz-Journal of Plant Diseases and Protection***,** 113-117.

DÖRING, T.F., BOCCI R, HITCHINGS, R., HOWLETT, S., LAMMERTS VAN BUEREN, E.T., PAUTASSO, M., RAAIJMAKERS, M., REY, F., STUBSGAARD, A., WEINHAPPEL, M., WILBOIS, K.P., WINKLER, L.R., WOLFE, M.S. 2012. The organic seed regulations framework in Europe-current status and recommendations for future development. *Organic agriculture* 2,173-183.

DRESBOLL, D. B., BJORN, G. K. & THORUP-KRISTENSEN, K. 2008. Yields and the extent and causes of damage in cauliflower, bulb onion, and carrot grown under organic or conventional regimes. *Journal of Horticultural Science & Biotechnology,* 83**,** 770-776.

DRINKWATER, L. E., LETOURNEAU, D. K., WORKNEH, F., BRUGGEN, A. H. C. V. & SHENNAN, C. 1995. Fundamental differences between conventional and organic tomato agroecosystems in California. *Ecological Applications,* 5**,** 1098-1112.

DUER, I. & FELEDYN-SZEWCZYK, B. 2001a. The effect of cropping system on weed species composition in the spring barley. *Roczniki Nauk Rolniczych,* 115**,** 91-107.

DUER, I. & FELEDYN-SZEWCZYK, B. 2001b. Interaction between cropping system and weed flora composition and soil seed bank in winter wheat. *Roczniki Nauk Rolniczych,* 115**,** 109-130.

DURAZZO, A., AZZINI, E., FODDAI, M. S., NOBILI, F., GARAGUSO, I., RAGUZZINI, A., FINOTTI, E., TISSELLI, V., VECCHIO, S. D., PIAZZA, C., PERENZIN, M., PLIZZARI, L. & MAIANI, G. 2010. Influence of different crop management practices on the nutritional properties and benefits of tomato Lycopersicon esculentum cv Perfectpeel. *International Journal of Food Science & Technology,* 45**,** 2637-2644.

EDESI, L., JARVAN, M., ADAMSON, A., LAURINGSON, E. & KUHT, J. 2012. Weed species diversity and community composition in conventional and organic farming: a five-year experiment. *Zemdirbyste,* 99**,** 339-346.
EDWARDS, S. G. 2009a. Fusarium mycotoxin content of UK organic and conventional barley. *Food Additives and Contaminants A,* 26**,** 1185-1190.
EDWARDS, S. G. 2009b. Fusarium mycotoxin content of UK organic and conventional oats. *Food Additives and Contaminants A,* 26**,** 1063-1069.
EDWARDS, S. G. 2009c. Fusarium mycotoxin content of UK organic and conventional wheat. *Food Additives and Contaminants A,* 26**,** 496-506.
EKEBERG, E., RILEY, H. & NJØS, A. 1985. Plogfri jordarbeiding til vårkorn: I. Avling og kveke. *Forsk. Fors. Landbruket,* 36**,** 45-51.
EKROOS, J., HYVONEN, T., TIAINEN, J. & TIIRA, M. 2010. Responses in plant and carabid communities to farming practises in boreal landscapes. *Agriculture Ecosystems & Environment,* 135**,** 288-293.
ELTUN, R. 1996a. The Apelsvoll cropping system experiment. III. Yield and grain quality of cereals. *Norwegian Journal of Agricultural Sciences,* 10**,** 7-22.
ELTUN, R. 1996b. The Apelsvoll cropping system experiment. IV. Yield and quality of potatoes, forage crops and entire cropping systems. *Norwegian Journal of Agricultural Sciences,* 10**,** 23-41.
ESCH, J. R., FRIEND, J. R. & KARIUKI, J. K. 2010. Determination of the Vitamin C Content of Conventionally and Organically Grown Fruits by Cyclic Voltammetry. *International Journal of Electrochemical Science,* 5**,** 1464-1474.
EUROLA, M., HIETANIEMI, V., KONTTURI, M., TUURI, H., KANGAS, A., NISKANEN, M. & SAASTAMOINEN, M. 2004. Selenium content of Finnish oats in 1997-1999: effect of cultivars and cultivation techniques. *Agricultural and Food Science,* 13**,** 46-53.
EYRE, M. D., CRITCHLEY, C. N. R., LEIFERT, C. & WILCOCKSON, S. J. 2011. Crop sequence, crop protection and fertility management effects on weed cover in an organic/conventional farm management trial. *European Journal of Agronomy,* 34**,** 153-162.
EYRE, M. D. & LEIFERT, C. 2011. Crop and field boundary influences on the activity of a wide range of beneficial invertebrate groups on a split conventional/organic farm in northern England. *Bulletin of entomological research,* 101**,** 135-144.
EYRE, M. D., LUFF, M. L., ATLIHAN, R. & LEIFERT, C. 2012. Ground beetle species (Carabidae, Coleoptera) activity and richness in relation to crop type, fertility management and crop protection in a farm management comparison trial. *Annals of Applied Biology,* 161**,** 169-179.
EYRE, M. D., LUFF, M. L. & LEIFERT, C. 2013. Crop, field boundary, productivity and disturbance influences on ground beetles (Coleoptera, Carabidae) in the agroecosystem. *Agriculture Ecosystems & Environment,* 165**,** 60-67.
EYRE, M. D., SANDERSON, R. A., SHOTTON, P. N. & LEIFERT, C. 2009. Investigating the effects of crop type, fertility management and crop protection on the activity of beneficial invertebrates in an extensive farm management comparison trial. *Annals of Applied Biology,* 155**,** 267-276.
FALCINELLI, M. 2007. Organic forage seed production for Mediterranean regions. *In:* ROSELLINI, D. & VERONESI, F. (eds.). Wageningen: European Association for Research on Plant Breeding (EUCARPIA).
FAO 2000. Food safety as affected by organic farming. Twenty second FAO regional conference for Europe. www.fao.org/organicag/frame2-e.html.

FEBER, R. E., FIRBANK, L. G., JOHNSON, P. J. & MACDONALD, D. W. 1997. The effects of organic farming on pest and non-pest butterfly abundance. *Agriculture, Ecosystems & Environment,* 64**,** 133-139.

FELEDYN-SZEWCZYK, B. 2012. The effectiveness of weed regulation methods in spring wheat cultivated in integrated, conventional and organic crop production systems. *Journal of Plant Protection Research,* 52**,** 486-493.

FELEDYN-SZEWCZYK, B. & DUER, I. 2006a. The comparison of the structure of weed community in winter wheat cultivated in different crop production systems using ecological indices. *Fragmenta Agronomica,* 23**,** 79-93.

FELEDYN-SZEWCZYK, B. & DUER, I. 2006b. Effectiveness of weed regulation methods in spring barley cultivated in different crop production systems. *Progress in Plant Protection,* 46**,** 45-52.

FELEDYN-SZEWCZYK, B. & DUER, I. 2006c. The using of ecological indices for weed soil seed bank analysis. *Fragmenta Agronomica,* 23**,** 67-78.

FELEDYN-SZEWCZYK, B. & DUER, I. 2007. Weed infestation in spring wheat cultivated in organic crop production system in comparison with other crop production systems. *Journal of Research and Applications in Agricultural Engineering,* 52**,** 40-44.

FELLESKJØPET 2013. ThermoSeed - Fremtidens såkorn. http://www.felleskjopet.no/landbruk/Sider/ThermoSeed---Fremtidens-sakorn.aspx Accessed 26 January 2014.

FELS-KLERX, H. J. V. D. & STRATAKOU, I. 2010. T-2 toxin and HT-2 toxin in grain and grain-based commodities in Europe: occurrence, factors affecting occurrence, co-occurrence and toxicological effects. (Special Issue: Human health issues.). *World Mycotoxin Journal,* 3**,** 349-367.

FERNANDES, V. C., DOMINGUES, V. F., FREITAS, V. D., DELERUE-MATOS, C. & MATEUS, N. 2012. Strawberries from integrated pest management and organic farming: phenolic composition and antioxidant properties. *Food Chemistry,* 134**,** 1926-1931.

FERRIS, H., VENETTE, R. C. & LAU, S. S. 1996. Dynamics of nematode communities in tomatoes grown in conventional and organic farming systems, and their impact on soil fertility. *Applied Soil Ecology,* 3**,** 161-175.

FISCHER, C., THIES, C. & TSCHARNTKE, T. 2011. Mixed effects of landscape complexity and farming practice on weed seed removal. *Perspectives in Plant Ecology Evolution and Systematics,* 13**,** 297-303.

FJELKNER-MODIG, S., BENGTSSON, H., STEGMARK, R. & NYSTROM, S. 2000. The influence of organic and integrated production on nutritional, sensory and agricultural aspects of vegetable raw materials for food production. *Acta Agriculturae Scandinavica,* 50**,** 102-113.

FJELKNER MODIG, S., BENGTSSON, H., STEGMARK, R. & NYSTROEM, S. 2000. The influence of organic and integrated production on nutritional, sensory and agricultural aspects of vegetable raw materials for food production. *Acta Agriculturae Scandinavica. Section B. Soil and Plant Science,* 50**,** 102-113.

FLIS, B., ZIMNOCH-GUZOWSKA, E. & MANKOWSKI, D. 2012. Correlations among yield, taste, tuber characteristics and mineral contents of potato cultivars grown at different growing conditions. *Journal of Agricultural Science,* 4**,** 197-207.

FORSBERG, G., ANDERSSON, S. & JOHNSSON, L. 2002. Evaluation of hot, humid air seed treatment in thin layers and fluidized beds for seed pathogen sanitation. *Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz,* 109**,** 357-370.

FRERE, I., SALIN, C., FABRY, J. & HANCE, T. 2005. Role of host plant alternation in the precocity and intensity of parasitoid activity on of cereal aphids. *Communications in agricultural and applied biological sciences,* 70**,** 581-591.
FRIED, G., NORTON, L. R. & REBOUD, X. 2008. Environmental and management factors determining weed species composition and diversity in France. *Agriculture, ecosystems & environment,* 128**,** 68-76.
FYKSE, H. 1983. Untersuchungen ueber Achillea millefolium L. und Achillea ptarmica L. Entwicklung der Pflanzen und Lebensdauer der vegetativen Vermehrungsorgane unter verschiedenen Bedingungen, zum Teil mit anderen Arten verglichen.-Studium av ryllik (Achillea millefolium L.) og nyseryllik (Achillea ptarmica L.). Utvikling av plantene og levetid for dei vegetative oekslingsorgana under ulike tilhoeve, dels jamfoert med andre arter. *Meldinger fra Norges Landbrukshoegskole*.
FYKSE, H. 1986. Experiments with Rumex species. Growth and regeneration. *Meldinger fra Norges Landbrukshoegskole (Norway)*.
GABRIEL, D. & TSCHARNTKE, T. 2007. Insect pollinated plants benefit from organic farming. *Agriculture Ecosystems & Environment,* 118**,** 43-48.
GAGIC, V., HANKE, S., THIES, C., SCHERBER, C., TOMANOVIC, Z. & TSCHARNTKE, T. 2012. Agricultural intensification and cereal aphid-parasitoid-hyperparasitoid food webs: Network complexity, temporal variability and parasitism rates. *Oecologia,* 170**,** 1099-1109.
GALLANDT, E. R., LIEBMAN, M., CORSON, S., PORTER, G. A. & ULLRICH, S. D. 1998. Effects of pest and soil management systems on weed dynamics in potato. *Weed science,* 46**,** 238-248.
GALLER, J. 1989. *Grünlandverunkrautung*, Stocker.
GALVAN, G. A., PARADI, I., BURGER, K., BAAR, J., KUYPER, T. W., SCHOLTEN, O. E. & KIK, C. 2009. Molecular diversity of arbuscular mycorrhizal fungi in onion roots from organic and conventional farming systems in the Netherlands. *Mycorrhiza,* 19**,** 317-328.
GARRATT, M. P. D., WRIGHT, D. J. & LEATHER, S. R. 2010. The effects of organic and conventional fertilizers on cereal aphids and their natural enemies. *Agricultural and Forest Entomology,* 12**,** 307-318.
GARRATT, M. P. D., WRIGHT, D. J. & LEATHER, S. R. 2011. The effects of farming system and fertilisers on pests and natural enemies: A synthesis of current research. *Agriculture Ecosystems & Environment,* 141**,** 261-270.
GAWEDA, M., NIZIOL-LUKASZEWSKA, Z. & SZOPINSKA, A. 2012. The contents of selected metals in carrot cultivated using conventional, integrated and organic method. *Acta Horticulturae,* 936**,** 257-263.
GEHERMAN, V., VIIRALT, R. & ELLERMAE, O. 2003. Comparison of leys on conventional and organic farms in Estonia. (Grassland Science in Europe Volume 8). *In:* KIRILOV, A., TODOROV, N. & KATEROV, I. (eds.). Pleven: Bulgarian Association for Grassland and Forage Production (BAGFP).
GILSENAN, C., BURKE, R. M. & BARRY-RYAN, C. 2010. A study of the physicochemical and sensory properties of organic and conventional potatoes (Solanum tuberosum) before and after baking. *International Journal of Food Science and Technology,* 45**,** 475-481.
GIRSCH, L. & WEINHAPPEL, M. 2004. Specific seed health standards for organic cereal seed. *Proceedings of the First World Conference on Organic Seed*. Challenges and Opportunities for Organic Agriculture and the Seed Industry, July 5-7, 2004, FAO Headquarters, Rome, Italy, p 79-83.

GLEMNITZ, M., RADICS, L., HOFFMANN, J. & CZIMBER, G. 2006. Weed species richness and species composition of different arable field types - A comparative analysis along a climate gradient from South to North Europe. *Journal of Plant Diseases and Protection*, 577-586.
GOLISZEWSKI, W. & ZARZYNSKA, K. 2008. Incidence of the aphids - vectors of potato viruses on organic and integrated plantation and health of seed potato tubers. *Journal of Research and Applications in Agricultural Engineering,* 53, 84-87.
GONZALEZ, M., MIGLIORANZA, K. S. B., AIZPUN DE MORENO, J. E. & MORENO, V. J. 2005. Evaluation of conventionally and organically produced vegetables for high lipophilic organochlorine pesticide (OCP) residues. *Food and Chemical Toxicology,* 43, 261-269.
GOODING, M. J. 2010. *The wheat crop, In: Wheat: Chemistry and Technology*.
GOSME, M., DE VILLEMANDY, M., BAZOT, M. & JEUFFROY, M. H. 2012. Local and neighbourhood effects of organic and conventional wheat management on aphids, weeds, and foliar diseases. *Agriculture Ecosystems & Environment,* 161, 121-129.
GOTTSCHALK, C., BARTHEL, J., ENGELHARDT, G., BAUER, J. & MEYER, K. 2007. Occurrence of type A trichothecenes in conventionally and organically produced oats and oat products. *Molecular Nutrition & Food Research,* 51, 1547-1553.
GRAGLIA, E., MELANDER, B. & JENSEN, R. K. 2006. Mechanical and cultural strategies to control Cirsium arvense in organic arable cropping systems. *Weed Research,* 46, 304-312.
GRAVEL, V., BLOK, W., HALLMANN, E., CARMONA-TORRES, C., WANG, H., PEPPEL, A. V. D., CONDOR GOLEC, A. F., DORAIS, M., MEETEREN, U. V., HEUVELINK, E., REMBIALKOWSKA, E. & BRUGGEN, A. H. C. V. 2010. Differences in N uptake and fruit quality between organically and conventionally grown greenhouse tomatoes. *Agronomy for Sustainable Development,* 30, 797-806.
GRAZIANI, F., ONOFRI, A., PANNACCI, E., TEI, F. & GUIDUCCI, M. 2012. Size and composition of weed seedbank in long-term organic and conventional low-input cropping systems. *European Journal of Agronomy,* 39, 52-61.
GRIESSHABER, D., KUHN, F., BERGER, U. & OEHME, M. 2004. Comparison of trichothecene contaminations in wheat cultivated by three different farming systems in Switzerland: biodynamic, bioorganic and conventional. *Mitteilungen aus Lebensmitteluntersuchung und Hygiene,* 95, 251-260.
GRIFFITHS, A. M., COOK, D. M., EGGETT, D. L. & CHRISTENSEN, M. J. 2012. A retail market study of organic and conventional potatoes (Solanum tuberosum): mineral content and nutritional implications. *International Journal of Food Sciences and Nutrition,* 63, 393-401.
GROOT, S.P.C., VAN DER WOLF, J.M., JALINK, H., LANGERAK, C.J., VAN DEN BULK, R.W. 2004. Challenges for the production of high quality organic seeds. Seed Testing International - *ISTA News Bull,* 127,12–15.
GRUBER, H., HANDEL, K. & BROSCHEWITZ, B. 2000. Influence of farming system on weeds in thresh crops of a six-year crop rotation. *Zeitschrift Fur Pflanzenkrankheiten Und Pflanzenschutz-Journal of Plant Diseases and Protection*, 33-40.
GUNDERSEN, V., BECHMANN, I. E., BEHRENS, A. & STURUP, S. 2000. Comparative investigation of concentrations of major and trace elements in organic and conventional Danish agricultural crops. 1. Onions (Allium cepa Hysam) and peas (Pisum sativum Ping Pong). *Journal of Agricultural and Food Chemistry,* 48, 6094-6102.

GUSTAFSON, G. M., SALOMON, E. & JONSSON, S. 2007. Barn balance calculations of Ca, Cu, K, Mg, Mn, N, P, S and Zn in a conventional and organic dairy farm in Sweden. *Agriculture, ecosystems & environment,* 119**,** 160-170.

HAGHIGHI, R. S., CRITCHLEY, N., LEIFERT, C., EYRE, M. & COOPER, J. 2013. Individual and interactive effects of crop type and management on weed and seed bank composition in an organic rotation. *International Journal of Plant Production,* 7**,** 243-268.

HAJSLOVA, J., SCHULZOVA, V., SLANINA, P., JANNE, K., HELLENAS, K. E. & ANDERSSON, C. 2005. Quality of organically and conventionally grown potatoes: four-year study of micronutrients, metals, secondary metabolites, enzymic browning and organoleptic properties. *Food Additives and Contaminants,* 22**,** 514-534.

HAKKINEN, S. H. & TORRONEN, A. R. 2000. Content of flavonols and selected phenolic acids in strawberries and Vaccinium species: influence of cultivar, cultivation site and technique. *Food Research International,* 33**,** 517-524.

HALD, A. B. 1999. Weed vegetation (wild flora) of long established organic versus conventional cereal fields in Denmark. *Annals of Applied Biology,* 134**,** 307-314.

HALLMANN, E. 2012. The influence of organic and conventional cultivation systems on the nutritional value and content of bioactive compounds in selected tomato types. *Journal of the Science of Food and Agriculture,* 92**,** 2840-2848.

HALLMANN, J., FRANKENBERG, A., PAFFRATH, A. & SCHMIDT, H. 2007. Occurrence and importance of plant-parasitic nematodes in organic farming in Germany. *Nematology,* 9**,** 869-880.

HAMOUZ, K., LACHMAN, J., DVORAK, P. & PIVEC, V. 2005. The effect of ecological growing on the potatoes yield and quality. *Plant, Soil and Environment,* 51**,** 397-402.

HANELL, U., L-BAECKSTROM, G. & SVENSSON, G. 2004. Quality studies on wheat grown in different cropping systems: a holistic perspective. *Acta Agriculturae Scandinavica,* 54**,** 254-263.

HANNUKKALA, A. O. & TAPIO, E. 1990. Conventional and organic cropping systems at Suitia [in Southern Finland], 5: Cereal diseases. *Journal of Agricultural Science in Finland (Finland). Maataloustieteellinen Aikakauskirja,* 62**,** 339-347.

HARCZ, P., TEMMERMAN, L. D., VOGHEL, S. D., WAEGENEERS, N., WILMART, O., VROMMAN, V., SCHMIT, J. F., MOONS, E., PETEGHEM, C. V., SAEGER, S. D., SCHNEIDER, Y. J., LARONDELLE, Y. & PUSSEMIER, L. 2007. Contaminants in organically and conventionally produced winter wheat (Triticum aestivum) in Belgium. *Food Additives and Contaminants,* 24**,** 713-720.

HARGREAVES, J. C., ADL, M. S., WARMAN, P. R. & RUPASINGHE, H. P. V. 2008. The effects of organic and conventional nutrient amendments on strawberry cultivation: fruit yield and quality. *Journal of the Science of Food and Agriculture,* 88**,** 2669-2675.

HECKE, K., HERBINGER, K., VEBERIC, R., TROBEC, M., TOPLAK, H., STAMPAR, F., KEPPEL, H. & GRILL, D. 2006. Sugar-, acid- and phenol contents in apple cultivars from organic and integrated fruit cultivation. *European Journal of Clinical Nutrition,* 60**,** 1136-1140.

HEIMLER, D., VIGNOLINI, P., ARFAIOLI, P., ISOLANI, L. & ROMANI, A. 2012. Conventional, organic and biodynamic farming: differences in polyphenol content and antioxidant activity of Batavia lettuce. *Journal of the Science of Food and Agriculture,* 92**,** 551-556.

HERENCIA, J. F., GARCIA-GALAVIS, P. A., DORADO, J. A. R. & MAQUEDA, C. 2011. Comparison of nutritional quality of the crops grown in an organic and conventional fertilized soil. *Scientia Horticulturae,* 129**,** 882-888.

HIETANIEMI, V., KONTTURI, M., RAMO, S., EUROLA, M., KANGAS, A., NISKANEN, M. & SAASTAMOINEN, M. 2004. Contents of trichothecenes in oats during official variety, organic cultivation and nitrogen fertilization trials in Finland. *Agricultural and Food Science,* 13**,** 54-67.

HILBER, I., MADER, P., SCHULIN, R. & WYSS, G. S. 2008. Survey of organochlorine pesticides in horticultural soils and there grown Cucurbitaceae. *Chemosphere,* 73**,** 954-961.

HILDERMANN, I., THOMMEN, A., DUBOIS, D., BOLLER, T., WIEMKEN, A. & MADER, P. 2009. Yield and baking quality of winter wheat cultivars in different farming systems of the DOK long-term trial. *Journal of the Science of Food and Agriculture,* 89**,** 2477-2491.

HILLGER, D. E., WELLER, S. C., MAYNARD, E. & GIBSON, K. D. 2006. Weed management systems in Indiana tomato production. *Weed Science,* 54**,** 516-520.

HILTBRUNNER, J., LIEDGENS, M., BLOCH, L., STAMP, P. & STREIT, B. 2007. Legume cover crops as living mulches for winter wheat: Components of biomass and the control of weeds. *European Journal of Agronomy,* 26**,** 21-29.

HILTBRUNNER, J., SCHERRER, C., STREIT, B., JEANNERET, P., ZIHLMANN, U. & TSCHACHTLI, R. 2008. Long-term weed community dynamics in Swiss organic and integrated farming systems. *Weed Research,* 48**,** 360-369.

HOEFKENS, C., VANDEKINDEREN, I., MEULENAER, B. D., DEVLIEGHERE, F., BAERT, K., SIOEN, I., HENAUW, S. D., VERBEKE, W. & CAMP, J. V. 2009. A literature-based comparison of nutrient and contaminant contents between organic and conventional vegetables and potatoes. (Special Issue: Organic farming - for environment and health.). *British Food Journal,* 111**,** 1078-1097.

HOLB, I. J. 2008. Monitoring conidial density of Monilinia fructigena in the air in relation to brown rot development in integrated and organic apple orchards. *European Journal of Plant Pathology,* 120**,** 397-408.

HOLB, I. J., DREMAK, P., BITSKEY, K. & GONDA, I. 2012. Yield response, pest damage and fruit quality parameters of scab-resistant and scab-susceptible apple cultivars in integrated and organic production systems. *Scientia Horticulturae,* 145**,** 109-117.

HOLB, I. J., HEIJNE, B. & JEGER, M. J. 2005a. The widespread occurrence of overwintered conidial inoculum of Venturia inaequalis on shoots and buds in organic and integrated apple orchards across the Netherlands. *European Journal of Plant Pathology,* 111**,** 157-168.

HOLB, I. J., HEIJNE, B., WITHAGEN, J. C. M., GALL, J. M. & JEGER, M. J. 2005b. Analysis of summer epidemic progress of apple scab at different apple production systems in the Netherlands and Hungary. *Phytopathology,* 95**,** 1001-1020.

HOLB, I. J. & SCHERM, H. 2007. Temporal dynamics of brown rot in different apple management systems and importance of dropped fruit for disease development. *Phytopathology,* 97**,** 1104-1111.

HOLZSCHUH, A., STEFFAN-DEWENTER, I., KLEIJN, D. & TSCHARNTKE, T. 2007. Diversity of flower-visiting bees in cereal fields: effects of farming system, landscape composition and regional context. *Journal of Applied Ecology,* 44**,** 41-49.

HOLZSCHUH, A., STEFFAN-DEWENTER, I. & TSCHARNTKE, T. 2008. Agricultural landscapes with organic crops support higher pollinator diversity. *Oikos,* 117**,** 354-361.

HOLZSCHUH, A., STEFFAN-DEWENTER, I. & TSCHARNTKE, T. 2010. How do landscape composition and configuration, organic farming and fallow strips affect the diversity of bees, wasps and their parasitoids? *Journal of Animal Ecology,* 79**,** 491-500.

HOOGENBOOM, L. A., BOKHORST, J. G., NORTHOLT, M. D., VAN DE VIJVER, L. P., BROEX, N. J., MEVIUS, D. J., MEIJS, J. A. & VAN DER ROEST, J. 2008. Contaminants and microorganisms in Dutch organic food products: a comparison with conventional products. *Food Additives & Contaminants. Part A, Chemistry, Analysis, Control, Exposure & Risk Assessment,* 25**,** 1195-207.
HUMMEL, R. L., WALGENBACH, J. F., HOYT, G. D. & KENNEDY, G. G. 2002. Effects of production system on vegetable arthropods and their natural enemies. *Agriculture Ecosystems & Environment,* 93**,** 165-176.
HUNTER, D., FOSTER, M., MCARTHUR, J. O., OJHA, R., PETOCZ, P. & SAMMAN, S. 2011. Evaluation of the micronutrient composition of plant foods produced by organic and conventional agricultural methods. *Critical Reviews in Food Science and Nutrition,* 51**,** 571-582.
HYVONEN, T. 2007. Can conversion to organic farming restore the species composition of arable weed communities? *Biological Conservation,* 137**,** 382-390.
HYVONEN, T., KETOJA, E., SALONEN, J., JALLI, H. & TIAINEN, J. 2003. Weed species diversity and community composition in organic and conventional cropping of spring cereals. *Agriculture Ecosystems & Environment,* 97**,** 131-149.
HYVONEN, T. & SALONEN, J. 2005. Biomass production of weeds in low-input and conventional cropping of cereals. *Biological Agriculture & Horticulture,* 23**,** 161-173.
HÅKANSSON, S. 2003. *Weeds and weed management on arable land: an ecological approach*, CABI.
HÅKANSSON, I., STENBERG, M. & RYDBERG, T. 1998. Long-term experiments with different depths of mouldboard ploughing in Sweden. *Soil & tillage research,* 46**,** 209-223.
IFOAM 2011. IFOAM position on the use of organic seed and plant propagation material in organic agriculture. http://www.ifoam.org/press/positions/Seed_Position_Paper.pdf Accessed 26 January 2014.: IFOAM, International Federation of Organic Agriculture Movements.
INGVER, A., TAMM, I. & TAMM, U. 2008. Effect of organic and conventional production on yield and the quality of spring cereals.
JACKSON, L.S. & AL-TAHER, F. 2008. Factors affecting mycotoxin production in Fruits. In: *Mycotoxins in Fruits and Vegetables*, edited by Barkai-Golan R and Paster N. Elsevier Inc. Chapter 4, 75-103
JAKOPIC, J., SLATNAR, A., STAMPAR, F., VEBERIC, R. & SIMONCIC, A. 2012. Analysis of selected primary metabolites and phenolic profile of 'Golden Delicious' apples from four production systems. *Fruits,* 67**,** 377-386.
JENSEN, B., KNUDSEN, I. M. B., ANDERSEN, B., NIELSEN, K. F., THRANE, U., JENSEN, D. F. & LARSEN, J. 2013. Characterization of microbial communities and fungal metabolites on field grown strawberries from organic and conventional production. *International Journal of Food Microbiology,* 160**,** 313-322.
JIN, P., WANG, S. Y., GAO, H. Y., CHEN, H. J., ZHENG, Y. H. & WANG, C. Y. 2012. Effect of cultural system and essential oil treatment on antioxidant capacity in raspberries. *Food Chemistry,* 132**,** 399-405.
JIN, P., WANG, S. Y., WANG, C. Y. & ZHENG, Y. 2011. Effect of cultural system and storage temperature on antioxidant capacity and phenolic compounds in strawberries. *Food Chemistry,* 124**,** 262-270.
JÖNSSSON, A., NYBOM, H. & RUMPUNEN, K. 2010. Fungal disease and fruit quality in an apple orchard converted from integrated production to organic production. *Journal of sustainable agriculture,* 34**,** 15-37.

JORDBRUKSVERKET 2013. Eko grönsaksodling. Nyhetsbrev nr 1 – Mars 2013: 2 pp, www.jordbruksverket.se/ekogronsaksbrev

JORHEM, L. & SLANINA, P. 2000. Does organic farming reduce the content of Cd and certain other trace metals in plant foods? A pilot study. *Journal of the Science of Food and Agriculture,* 80**,** 43-48.

JOSE-MARIA, L. & SANS, F. X. 2011. Weed seedbanks in arable fields: effects of management practices and surrounding landscape. *Weed Research,* 51**,** 631-640.

JØRGENSEN, H., KNUDSEN, K. E. B. & LAURIDSEN, C. 2012. Influence of different cultivation methods on carbohydrate and lipid compositions and digestibility of energy of fruits and vegetables. *Journal of the Science of Food and Agriculture,* 92**,** 2876-2882.

JØRGENSEN, K. & JACOBSEN, J. S. 2002. Occurrence of ochratoxin A in Danish wheat and rye, 1992-99. *Food Additives and Contaminants,* 19**,** 1184-1189.

JØRGENSEN, K., RASMUSSEN, G. & THORUP, I. 1996. Ochratoxin A in Danish cereals 1986–1992 and daily intake by the Danish population. *Food Additives & Contaminants,* 13**,** 95-104.

KAHU, K., JANES, H., LUIK, A. & KLAAS, L. 2009. Yield and fruit quality of organically cultivated blackcurrant cultivars. *Acta Agriculturae Scandinavica,* 59**,** 63-69.

KAHU, K., KLAAS, L. & KIKAS, A. 2010. Effect of cultivars and different growing technologies on strawberry yield and fruit quality. *Agronomy Research,* 8**,** 589-594.

KAPUSTA-DUCH, J. & LESZCZYNSKA, T. 2013. Comparison of Vitamin C and beta-Carotene in Cruciferous Vegetables Grown in Diversified Ecological Conditions. *Polish Journal of Environmental Studies,* 22**,** 167-173.

KAPUSTA-DUCH, J., LESZCZYNSKA, T. & FILIPIAK-FLORKIEWICZ, A. 2012. Comparison of total polyphenol contents and antioxidant activity in cruciferous vegetables grown in diversified ecological conditions. *Acta Scientiarum Polonorum Technologia Alimentaria,* 11**,** 335-346.

KARKANIS, A., BILALIS, D., EFTHIMIADOU, A. & KATSENIOS, N. 2012. Comparison between conventional and organic weed management: growth and yield of leek (Allium porrum L.). *Horticultural Science,* 39**,** 81-88.

KAUT, A. H. E. E., MASON, H. E., NAVABI, A., O'DONOVAN, J. T. & SPANER, D. 2008. Organic and conventional management of mixtures of wheat and spring cereals. *Agronomy for Sustainable Development,* 28**,** 363-371.

KAUT, A. H. E. E., MASON, H. E., NAVABI, A., O'DONOVAN, J. T. & SPANER, D. 2009. Performance and stability of performance of spring wheat variety mixtures in organic and conventional management systems in western Canada. *Journal of Agricultural Science,* 147**,** 141-153.

KAZIMIERCZAK, R., HALLMANN, E., RUSACZONEK, A. & REMBIALKOWSKA, E. 2008. Antioxidant content in black currants from organic and conventional cultivation. *Electronic Journal of Polish Agricultural Universities,* 11.

KEISER, A., HABERLI, M. & STAMP, P. 2012. Quality deficiencies on potato (Solanum tuberosum L.) tubers caused by Rhizoctonia solani, wireworms (Agriotes ssp.) and slugs (Deroceras reticulatum, Arion hortensis) in different farming systems. *Field Crops Research,* 128**,** 147-155.

KIRCHMANN, H., BERGSTROM, L., KATTERER, T., MATTSSON, L. & GESSLEIN, S. 2007. Comparison of long-term organic and conventional crop-livestock systems on a previously nutrient-depleted soil in Sweden. *Agronomy Journal,* 99**,** 960-972.

KNIGHT, A. 1994. Insect pest and natural enemy populations in paired organic and conventional apple orchards in the Yakima Valley, Washington. *Journal of the Entomological Society of British Columbia,* 91**,** 27-36.

KNIGHT, A. L., BRUNNER, J. F. & ALSTON, D. 1994. Survey of azinphosmethyl resistance in codling moth (Lepidoptera: Tortricidae) in Washington and Utah. *Journal of economic entomology,* 87**,** 285-292.

KNUDSEN, I. M. B., DEBOSZ, K., HOCKENHULL, J., JENSEN, D. F. & ELMHOLT, S. 1999. Suppressiveness of organically and conventionally managed soils towards brown foot rot of barley. *Applied Soil Ecology,* 12**,** 61-72.

KOCH, G. 1991. Fungal pathogens on winter wheat in comparison of two conventional farms and one biodynamic farm in Hesse (FRG) 1986/87. *Zeitschrift fuer Pflanzenkrankheiten und Pflanzenschutz,* 98**,** 125-136.

KONOPACKA, D., KACZMAREK, U., MATULSKA, A., WAWRZYNCZAK, A., KRUCZYNSKA, D. & RUTKOWSKI, K. P. 2012. The comparison of sensory quality and processing potential of 'Topaz' apples grown in organic orchards and orchards managed in integrated production system. *Journal of Fruit and Ornamental Plant Research,* 20**,** 51-61.

KORSMO, E. 1954. Ugras i nåtidens jordbruk.

KOSS, A. M., JENSEN, A. S., SCHREIBER, A., PIKE, K. S. & SNYDER, W. E. 2005. Comparison of predator and pest communities in Washington potato fields treated with broad-spectrum, selective, or organic insecticides. *Environmental Entomology,* 34**,** 87-95.

KOVALEV, N. G., MITROFANOV, Y. I. & MITROFANOVA, G. N. 1995. Biologized systems of agriculture on drained soils. *Russian Agricultural Sciences,* 10**,** 1-3.

KOUWENHOVEN, J.K., PERDOK, U.D., BOER, J., OOMEN, G.J.M., 2002. Soil management by shallow mouldboard ploughing in The Netherlands, *Soil & Tillage Research*, 65, 125-139.

KRAGTEN, S., TAMIS, W. L. M., GERTENAAR, E., RAMIRO, S. M. M., POLL, R. J. V. D., WANG, J. & SNOO, G. R. D. 2011. Abundance of invertebrate prey for birds on organic and conventional arable farms in the Netherlands. *Bird Conservation International,* 21**,** 1-11.

KRALOVA, J., HAJSLOVA, J., POUSTKA, J., HOCHMAN, M., BJELKOVA, M. & ODSTRCILOVA, L. 2006. Occurrence of Alternaria toxins in fibre flax, linseed, and peas grown in organic and conventional farms: monitoring pilot study.

KRAUSS, J., GALLENBERGER, I. & STEFFAN-DEWENTER, I. 2011. Decreased Functional Diversity and Biological Pest Control in Conventional Compared to Organic Crop Fields. *Plos One,* 6.

KRAWCZYK, R., MATYSIAK, K., KIERZEK, R., KACZMAREK, S. & HOROSZKIEWICZ-JANKA, J. 2010. The effect of weed infestation of winter wheat within conversion to organic farming. *Journal of Research and Applications in Agricultural Engineering,* 55**,** 195-199.

KREJCIROVA, L., CAPOUCHOVA, I., PETR, J., BICANOVA, E. & KVAPIL, R. 2006. Protein composition and quality of winter wheat from organic and conventional farming. *Zemdirbyste, Mokslo Darbai,* 93**,** 285-296.

KRISTENSEN, K. & ERICSON, L. 2008. Importance of growth characteristics for yield of barley in different growing systems: will growth characteristics describe yield differently in different growing systems? *Euphytica,* 163**,** 367-380.

KRISTENSEN, L. 2003. Maternal effects due to organic and conventional growing conditions in spring barley (Hordeum vulgare). *Biological Agriculture & Horticulture,* 21**,** 195-208.

KRISTENSEN, M., OSTERGAARD, L. F., HALEKOH, U., JORGENSEN, H., LAURIDSEN, C., BRANDT, K. & BUGEL, S. 2008. Effect of plant cultivation methods on content of major and trace elements in foodstuffs and retention in rats. *Journal of the Science of Food and Agriculture,* 88**,** 2161-2172.

KRISTL, J., KRAJNC, A. U., KRAMBERGER, B. & MLAKAR, S. G. 2013. Strawberries From Integrated and Organic Production: Mineral Contents and Antioxidant Activity. *Acta Chimica Slovenica,* 60**,** 19-25.

KUS, J., JONCZYK, K., STALENGA, J., FELEDYN-SZEWCZYK, B. & MROZ, A. 2010. Yields of the selected winter wheat varieties cultivated in organic and conventional crop production systems. *Journal of Research and Applications in Agricultural Engineering,* 55**,** 219-223.

KUZDRALIŃSKI, A., SOLARSKA, E. & MAZURKIEWICZ, J. 2013. Mycotoxin content of organic and conventional oats from southeastern Poland. *Food Control,* 33**,** 68-72.

L-BAECKSTROM, G., HANELL, U. & SVENSSON, G. 2004. Baking quality of winter wheat grown in different cultivating systems, 1992-2001: a holistic approach. *Journal of sustainable agriculture,* 24**,** 53-79.

L-BAECKSTROM, G., LUNDEGARDH, B. & HANELL, U. 2006. The interactions between nitrogen dose, year and stage of ripeness on nitrogen and trace element concentrations and seed-borne pathogens in organic and conventional wheat. *Journal of the Science of Food and Agriculture,* 86**,** 2560-2578.

LACKO-BARTOSOVA, M. & KOBIDA, L. 2011. Deoxynivalenol and zearalenone in winter wheat grown in ecological and integrated systems. *Research Journal of Agricultural Science,* 43**,** 68-72.

LAIRON, D. 2010. Nutritional quality and safety of organic food. A review. *Agronomy for Sustainable Development,* 30**,** 33-41.

LAMPERI, L., CHIUMINATTO, U., CINCINELLI, A., GALVAN, P., GIORDANI, E., LEPRI, L. & DEL BUBBA, M. 2008. Polyphenol levels and free radical scavenging activities of four apple cultivars from integrated and organic farming in different Italian areas. *Journal of Agricultural and Food Chemistry,* 56**,** 6536-6546.

LANGENKAMPER, G., ZORB, C., SEIFERT, M., MADER, P., FRETZDORFF, B. & BETSCHE, T. 2006. Nutritional quality of organic and conventional wheat. *Journal of Applied Botany and Food Quality,* 80**,** 150-154.

LAUBER, U., SCHNAUFER, R., GREDZIAK, M. & KIESSWETTER, Y. 2005. Analysis of rye grains and rye meals for ergot alkaloids. *Mycotoxin Research,* 21**,** 258-262.

LEHESRANTA, S. J., KOISTINEN, K. M., MASSAT, N., DAVIES, H. V., SHEPHERD, L. V. T., MCNICOL, J. W., CAKMAK, I., COOPER, J., LUCK, L., KARENLAMPI, S. O. & LEIFERT, C. 2007. Effects of agricultural production systems and their components on protein profiles of potato tubers. *Proteomics,* 7**,** 597-604.

LEMANCZYK, G. 2012. Effects of farming system, chemical control, fertilizer and sowing density on sharp eyespot and Rhizoctonia spp. in winter wheat. *Journal of Plant Protection Research,* 52**,** 381-396.

LENC, L. 2006. Rhizoctonia solani and Streptomyces scabies on sprouts and tubers of potato grown in organic and integrated systems, and fungal communities in the soil habitat. *Phytopathologia Polonica,* 42**,** 13-28.

LENC, L., KWASNA, H. & SADOWSKI, C. 2012. Microbial Communities in Potato Roots and Soil in Organic and Integrated Production Systems Compared by the Plate Culturing Method. *Journal of Phytopathology,* 160**,** 337-345.

LESTER, G. E. & SAFTNER, R. A. 2011. Organically versus conventionally grown produce: Common production inputs, nutritional quality, and nitrogen delivery between the two systems. *Journal of Agricultural and Food Chemistry,* 59**,** 10401-10406.

LETOURNEAU, D. K. & BOTHWELL, S. G. 2008. Comparison of organic and conventional farms: challenging ecologists to make biodiversity functional. *Frontiers in Ecology and the Environment,* 6**,** 430-438.
LETOURNEAU, D. K. & GOLDSTEIN, B. 2001. Pest damage and arthropod community structure in organic vs. conventional tomato production in California. *Journal of Applied Ecology,* 38**,** 557-570.
LISOWICZ, F. 1999. The occurrence of cereal crop diseases depending on the system of farming. *Journal of Plant Protection Research,* 39**,** 116-131.
LOHAUS, K., VIDAL, S. & THIES, C. 2013. Farming practices change food web structures in cereal aphid-parasitoid-hyperparasitoid communities. *Oecologia,* 171**,** 249-259.
LOMBARDI-BOCCIA, G., LUCARINI, M., LANZI, S., AGUZZI, A. & CAPPELLONI, M. 2004. Nutrients and antioxidant molecules in yellow plums (Prunus domestica L.) from conventional and organic productions: a comparative study.[Erratum appears in J Agric Food Chem. 2006 May 17;54(10):3764]. *Journal of Agricultural & Food Chemistry,* 52**,** 90-4.
LOMBARDO, S., MONACO, A. L., PANDINO, G., PARISI, B. & MAUROMICALE, G. 2013. The phenology, yield and tuber composition of 'early' crop potatoes: a comparison between organic and conventional cultivation systems. *Renewable Agriculture and Food Systems,* 28**,** 50-58.
LOMBARDO, S., PANDINO, G. & MAUROMICALE, G. 2012. Nutritional and sensory characteristics of "early" potato cultivars under organic and conventional cultivation systems. (Special issue: Advances in potato chemistry, nutrition and technology.). *Food Chemistry,* 133**,** 1249-1254.
LOUARN, S., NAWROCKI, A., EDELENBOS, M., JENSEN, D. F., JENSEN, O. N., COLLINGE, D. B. & JENSEN, B. 2012. The influence of the fungal pathogen Mycocentrospora acerina on the proteome and polyacetylenes and 6-methoxymellein in organic and conventionally cultivated carrots (Daucus carota) during post harvest storage. *Journal of Proteomics,* 75**,** 962-977.
LUCARINI, M., D'EVOLI, L., TUFI, S., GABRIELLI, P., PAOLETTI, S., DI FERDINANDO, S. & LOMBARDI-BOCCIA, G. 2012. Influence of growing system on nitrate accumulation in two varieties of lettuce and red radicchio of Treviso. *Journal of the Science of Food and Agriculture,* 92**,** 2796-2799.
LUECK, L., SCHMIDT, C. S., COOPER, J. M., HALL, C. M., SHOTTON, P. N. & LEIFERT, C. 2006. Effect of organic, low-input and conventional production systems on yield and quality of winter wheat. *Aspects of Applied Biology,* 80**,** 135-140.
LUKANOWSKI, A. 2005. Winter wheat root health and fungi occurring on them in 1999-2002 depending on cultivation system. *Phytopathologia Polonica,* 38**,** 21-34.
LUNDKVIST, A. 2009. Effects of pre-and post-emergence weed harrowing on annual weeds in peas and spring cereals. *Weed research,* 49**,** 409-416.
MAALOULY, M., FRANCK, P., BOUVIER, J. C., TOUBON, J. F. & LAVIGNE, C. 2013. Codling moth parasitism is affected by semi-natural habitats and agricultural practices at orchard and landscape levels. *Agriculture, Ecosystems & Environment,* 169**,** 33-42.
MACFADYEN, S., GIBSON, R., RASO, L., SINT, D., TRAUGOTT, M. & MEMMOTT, J. 2009. Parasitoid control of aphids in organic and conventional farming systems. *Agriculture Ecosystems & Environment,* 133**,** 14-18.
MADER, P., HAHN, D., DUBOIS, D., GUNST, L., ALFOLDI, T., BERGMANN, H., OEHME, M., AMADO, R., SCHNEIDER, H., GRAF, U., VELIMIROV, A., FLIESSBACH, A. & NIGGLI, U. 2007. Wheat quality in organic and conventional farming: results of a 21 year field experiment. *Journal of the Science of Food and Agriculture,* 87**,** 1826-1835.

MAGGIO, A., CARILLO, P., BULMETTI, G. S., FUGGI, A., BARBIERI, G. & DE PASCALE, S. 2008. Potato yield and metabolic profiling under conventional and organic farming. *European Journal of Agronomy,* 28**,** 343-350.

MAGKOS, F., ARVANITI, F. & ZAMPELAS, A. 2003. Organic food: nutritious food or food for thought? A review of the evidence. *International Journal of Food Sciences and Nutrition,* 54**,** 357-371.

MAGNANI, S., BARUZZI, G., BONOLI, M., D'ANTUONO, L. F., ELEMENTI, S. & MALTONI, M. L. 2009. Effect of integrated pest management and organic cropping systems on strawberry-fruit health components and fruit quality. *Acta Horticulturae,* 842**,** 927-930.

MAGNUSSON, C., HAMMERAAS, B. & PLANTEVERNET, P. 2000. Rotgallnematoden Meloidogyne hapla i gulrot og kepaløk. *Grønn Forskning,* 2**,** 143-152.

MALMAURET, L., PARENT-MASSIN, D., HARDY, J. L. & VERGER, P. 2002. Contaminants in organic and conventional foodstuffs in France. *Food Additives and Contaminants,* 19**,** 524-532.

MANICI, L. M., CIAVATTA, C., KELDERER, M. & ERSCHBAUMER, G. 2003. Replant problems in South Tyrol: role of fungal pathogens and microbial population in conventional and organic apple orchards. *Plant and Soil,* 256**,** 315-324.

MARSHALL, A.H. & HUMPHREYS, M.O. 2002. Challenges in organic forage seed production. In: Powell, Jane and et al., (Eds*.) Proceedings of the UK Organic Research 2002 Conference,* Organic Centre Wales, Institute of Rural Studies, University of Wales Aberystwyth, pp. 95-96.

MARTINEZ-TOME, M., MARISCAL, M., MARTINEZ-TOME, J. & MARTINEZ-TOME, M. J. 2011. Proximate composition and anti-oxidant activities of organically- and conventionally-grown broccoli (Brassica oleracea L. var. italica). *Journal of Horticultural Science and Biotechnology,* 86**,** 511-516.

MARX, H., GEDEK, B. & KOLLARCZIK, B. 1995. Comparative investigations of mycotoxological status of alternatively and conventionally grown crops. [German].Vergleichende Untersuchungen zum mykotoxikologischen Status von okologisch und konventionell angebautem Getreide. *Zeitschrift fur Lebensmittel-Untersuchung und -Forschung,* 201**,** 83-86.

MASON, H., NAVABI, A., FRICK, B., O'DONOVAN, J., NIZIOL, D. & SPANER, D. 2007a. Does growing Canadian Western Hard Red Spring wheat under organic management alter its breadmaking quality? *Renewable Agriculture and Food Systems,* 22**,** 157-167.

MASON, H. E., NAVABI, A., FRICK, B. L., O'DONOVAN, J. T. & SPANER, D. M. 2007b. The weed-competitive ability of Canada western red spring wheat cultivars grown under organic management. *Crop Science,* 47**,** 1167-1176.

MASON, H. E. & SPANER, D. 2006. Competitive ability of wheat in conventional and organic management systems: a review of the literature. *Canadian Journal of Plant Science,* 86**,** 333-343.

MATEOS, I., RANILLA, M. J., DIAZ, A., PALACIOS, C., SARO, C., TEJIDO, M. L. & CARRO, M. D. 2010. Yield, chemical composition and ruminal degradability of winter wheat grown under organic and conventional management. *Journal of Dairy Science,* 93**,** 348-349.

MATES, S. G., PERFECTO, I. & BADGLEY, C. 2012. Parasitoid wasp diversity in apple orchards along a pest-management gradient. *Agriculture Ecosystems & Environment,* 156**,** 82-88.

MATHERS, J. C. & DAWSON, L. D. 1991. Large bowel fermentation in rats eating processed potatoes. *British Journal of Nutrition,* 66**,** 313-329.

MATTHEWS, R. A. J. 2002. Response to Worthington on nutritional quality of organic versus conventional fruits, vegetables, and grains [1]. *Journal of Alternative and Complementary Medicine,* 8**,** 695-696.
MATUSINSKY, P., MIKOLASOVA, R., KLEM, K., SPITZER, T. & URBAN, T. 2008. The role of organic vs. conventional farming practice, soil management and preceding crop on the incidence of stem-base pathogens on wheat. *Journal of Plant Diseases and Protection,* 115**,** 17-22.
MEISTER, U. 2009. Fusarium toxins in cereals of integrated and organic cultivation from the Federal State of Brandenburg (Germany) harvested in the years 2000-2007. *Mycotoxin Research,* 25**,** 133-139.
MELANDER, B., RASMUSSEN, I. A. & BARBERI, P. 2005. Integrating physical and cultural methods of weed control - Examples from European research. *Weed Science,* 53**,** 369-381.
MENALLED, F. D., SMITH, R. G., DAUER, J. T. & FOX, T. B. 2007. Impact of agricultural management on carabid communities and weed seed predation. *Agriculture Ecosystems & Environment,* 118**,** 49-54.
MIKULA, J., LASKA, V., SARAPATKA, B., TUFOVA, J. & TUF, I. H. 2011. Soil invertebrates in conventionally and organically farmed fields of winter wheat and winter oilseed rape in the Czech Republic. *Acta Societatis Zoologicae Bohemicae,* 75**,** 85-89.
MIKULIC-PETKOVSEK, M., SLATNAR, A., STAMPAR, F. & VEBERIC, R. 2010. The influence of organic/integrated production on the content of phenolic compounds in apple leaves and fruits in four different varieties over a 2-year period. *Journal of the Science of Food and Agriculture,* 90**,** 2366-2378.
MILICZKY, E. R., CALKINS, C. O. & HORTON, D. R. 2000. Spider abundance and diversity in apple orchards under three insect pest management programmes in Washington State, U.S.A. *Agricultural and Forest Entomology,* 2**,** 203-215.
MINARRO, M. 2012. Weed communities in apple orchards under organic and conventional fertilization and tree-row management. *Crop Protection,* 39**,** 89-96.
MINARRO, M., ESPADALER, X., MELERO, V. X. & SUAREZ-ALVAREZ, V. 2009. Organic versus conventional management in an apple orchard: effects of fertilization and tree-row management on ground-dwelling predaceous arthropods. *Agricultural and Forest Entomology,* 11**,** 133-142.
MITCHELL, A. E., HONG, Y. J., KOH, E. M., BARRETT, D. M., BRYANT, D. E., DENISON, R. F. & KAFFKA, S. 2007. Ten-year comparison of the influence of organic and conventional crop management practices on the content of flavonoids in tomatoes. *Journal of Agricultural and Food Chemistry,* 55**,** 6154-6159.
MORANDIN, L.A. & WINSTON, M.L. 2005. Wild bee abundance and seed production in conventional, organic, and genetically modified canola. *Ecological Applications* 15:871–881
MOREBY, S. J. 1996. The effects of organic and conventional farming methods on plant bug densities (Hemiptera: Heteroptera) within winter wheat fields. *Annals of Applied Biology,* 128**,** 415-421.
MOREBY, S. J., AEBISCHER, N. J., SOUTHWAY, S. E. & SOTHERTON, N. W. 1994. A COMPARISON OF THE FLORA AND ARTHROPOD FAUNA OF ORGANICALLY AND CONVENTIONALLY GROWN WINTER-WHEAT IN SOUTHERN ENGLAND. *Annals of Applied Biology,* 125**,** 13-27.
MOREBY, S. J. & SOTHERTON, N. W. 1997. A comparison of some important chick-food insect groups found in organic and conventionally-grown winter wheat fields in southern England. *Biological Agriculture and Horticulture,* 15**,** 51-60.

MOSCHINI, V., MIGLIORINI, P., SACCHETTI, P., CASELLA, G. & VAZZANA, C. 2012. Presence of aphid predators in common wheat (Triticum aestivum L.) in organic and conventional agroecosystems of Tuscany. *New Medit,* 11**,** 58-61.

MOSSÉ, J. & HUET, J. 1990. Amino acid composition and nutritional score for ten cereals and six legumes or oilseeds: causes and ranges of variations according to species and to seed nitrogen content. *Sciences des Aliments,* 10**,** 151-173.

MOSSÉ, J., HUET, J. & BAUDET, J. 1985. The amino acid composition of wheat grain as a function of nitrogen content. *Journal of cereal science,* 3**,** 115-130.

MÅGE, F. S., G. 1992. Orchard soil management systems. Effect on growth and fertility of apple trees. *Norwegian Journal of Agricultural Sciences* 6**,** 121-132.

NAGY-GASZTONYI, M., SASS-KISS, A., TOMOSKOZI-FARKAS, R., BANATI, D. & DAOOD, H. G. 2010. Liquid chromatographic analysis of phenolic compounds in organically and conventionally grown varieties of sour cherries. *Chromatographia,* 71**,** S99-S102.

NAGY, P. T., BIRO, T., NYEKI, J. & SZABO, Z. 2013. Comparative study of organic and integrated apple growing: differences in fruit nutrition. *Communications in soil science and plant analysis,* 44**,** 678-687.

NAGY, P. T., NYEKI, J. & SZABO, Z. 2012a. Are organic apples really healthier? *Acta Horticulturae,* 933**,** 607-611.

NAGY, P. T., NYEKI, J. & SZABO, Z. 2012b. Comparative study of nutrient availability in integrated and organic apple orchards. *Acta Horticulturae,* 933**,** 227-231.

NAVNTOFT, S., WRATTEN, S. D., KRISTENSEN, K. & ESBJERG, P. 2009. Weed seed predation in organic and conventional fields. *Biological Control,* 49**,** 11-16.

NAZARKO, O. M., VAN ACKER, R. C., ENTZ, M. H., SCHOOFS, A. & MARTENS, G. 2003. Pesticide free production of field crops: Results of an on-farm pilot project. *Agronomy Journal,* 95**,** 1262-1273.

NEACSU, A., SERBAN, G., TUTA, C. & TONCEA, I. 2010. Baking quality of wheat cultivars, grown in organic, conventional and low input agricultural systems. *Romanian Agricultural Research,* 27**,** 35-42.

NEHER, D. A. 1999. Nematode communities in organically and conventionally managed agricultural soils. *Journal of Nematology,* 31**,** 142.

NELSON, A. G., QUIDEAU, S., FRICK, B., NIZIOL, D., CLAPPERTON, J. & SPANER, D. 2011a. Spring wheat genotypes differentially alter soil microbial communities and wheat breadmaking quality in organic and conventional systems. *Canadian Journal of Plant Science,* 91**,** 485-495.

NELSON, A. G., QUIDEAU, S. A., FRICK, B., HUCL, P. J., THAVARAJAH, D., CLAPPERTON, M. J. & SPANER, D. M. 2011b. The soil microbial community and grain micronutrient concentration of historical and modern hard red spring wheat cultivars grown organically and conventionally in the black soil zone of the Canadian prairies. *Sustainability,* 3**,** 500-517.

NGOUAJIO, M. & MCGIFFEN, M. E., JR. 2004. Sustainable vegetable production: effects of cropping systems on weed and insect population dynamics. *Acta Horticulturae,* 638**,** 77-83.

NIELSEN, B.J. 2001. Toleranser for forekomst af udsædsbårne sygdomme i økologisk såsæd. *FØJO-rapport 15/2001*. Forædling af korn og bælgsæd samt produktion af såsæd i økolgisk jordbrug, 51-63.

NIELSEN, B. J., NIELSEN, G. C., PEDERSEN, J. B. & TERSBOL, M. 1999. Possibilities for production of organic, healthy seed. *DJF Rapport, Markbrug,* 10**,** 29-40.

NISKANEN, M. Organic forage seed production in Finland. First World Conference on Organic Seed. Challenges and Opportunities for Organic Agriculture and the Seed Industry, July 5-7, 2004 2004 FAO Headquarters, Rome, Italy. 145-148.

NJOROGE, S. M. C., KABIR, Z., MARTIN, F. N., KOIKE, S. T. & SUBBARAO, K. V. 2009. Comparison of Crop Rotation for Verticillium Wilt Management and Effect on Pythium Species in Conventional and Organic Strawberry Production. *Plant Disease,* 93**,** 519-527.

NOBILI, F., FINOTTI, E., FODDAI, M. S., AZZINI, E., GARAGUSO, I., RAGUZZINI, A., TISSELLI, V., PIAZZA, C., DURAZZO, A. & MAIANI, G. 2008. Bioactive compounds in tomatoes: effect of organic vs conventional management in Parma in 2006. *In:* NEUHOFF, D., HALBERG, N., ALFOLDI, T., LOCKERETZ, W., THOMMEN, A., RASMUSSEN, I. A., HERMANSEN, J., VAARST, M., LUECK, L., CAPORALI, F., JENSEN, H. H., MIGLIORINI, P. & WILLER, H. (eds.). Bonn: Cultivating the future based on science Volume 2, International Society of Organic Agricultural Research (ISOFAR).

O'SULLIVAN, C. M. & GORMALLY, M. J. 2002. A comparison of ground beetle (Carabidae : coleoptera) communities in an organic and conventional potato crop. *Biological Agriculture & Horticulture,* 20**,** 99-110.

OBERG, S. 2007. Diversity of spiders after spring sowing - influence of farming system and habitat type. *Journal of Applied Entomology,* 131**,** 524-531.

OKADA, H., HASEGAWA, H., HASHIMOTO, T., SEKIGUCHI, H. & URASHIMA, Y. 2009. Are community structures of soil nematodes different between organic and conventional farming systems in commercial tomato fields? *Nematological Research,* 39**,** 63-71.

ORDONEZ-SANTOS, L. E., ARBONES-MACINEIRA, E., FERNANDEZ-PEREJON, J., LOMBARDERO-FERNANDEZ, M., VAZQUEZ-ODERIZ, L. & ROMERO-RODRIGUEZ, A. 2009. Comparison of physicochemical, microscopic and sensory characteristics of ecologically and conventionally grown crops of two cultivars of tomato (Lycopersicon esculentum Mill.). *Journal of the Science of Food and Agriculture,* 89**,** 743-749.

ORDONEZ-SANTOS, L. E., VAZQUEZ-ODERIZ, M. L. & ROMERO-RODRIGUEZ, M. A. 2011. Micronutrient contents in organic and conventional tomatoes (Solanum lycopersicum L.). *International Journal of Food Science & Technology,* 46**,** 1561-1568.

OSMAN, A., ALMEKINDERS, C., STRUIK, P. & VAN BUEREN, E. L. 2008. Can conventional breeding programmes provide onion varieties that are suitable for organic farming in the Netherlands? *Euphytica,* 163**,** 511-522.

OSTMAN, O., EKBOM, B. & BENGTSSON, J. 2003. Yield increase attributable to aphid predation by ground-living polyphagous natural enemies in spring barley in Sweden. *Ecological Economics,* 45**,** 149-158.

OSTMAN, O., EKBOM, B., BENGTSSON, J. & WEIBULL, A. C. 2001. Landscape complexity and farming practice influence the condition of polyphagous carabid beetles. *Ecological Applications,* 11**,** 480-488.

PALMER, M. W., COOPER, J., TETARD-JONES, C., SREDNICKA-TOBER, D., BARANSKI, M., EYRE, M., SHOTTON, P. N., VOLAKAKIS, N., CAKMAK, I., OZTURK, L., LEIFERT, C., WILCOCKSON, S. J. & BILSBORROW, P. E. 2013. The influence of organic and conventional fertilisation and crop protection practices, preceding crop, harvest year and weather conditions on yield and quality of potato (Solanum tuberosum) in a long-term management trial. *European Journal of Agronomy,* 49**,** 83-92.

PANASIEWICZ, K., KOZIARA, W. & KRAWCZYK, R. 2010. Comparison of grain sowing quality and vigor of spring barley grown in accordance with organic and conventional system. *Journal of Research and Applications in Agricultural Engineering,* 55**,** 42-45.

PANASIEWICZ, K., KOZIARA, W., SULEWSKA, H. & KRAWCZYK, R. 2011. Sowing quality and vigor of winter wheat grain, growing in accordance with the organic and conventional system. *Journal of Research and Applications in Agricultural Engineering,* 56**,** 58-61.

PECK, G. & MERWIN, I. 2010. Multi-level comparisons of organic and integrated fruit production systems for 'Liberty' apple in New York. *Acta Horticulturae,* 873**,** 57-66.

PECK, G. M., ANDREWS, P. K., REGANOLD, J. P. & FELLMAN, J. K. 2006. Apple orchard productivity and fruit quality under organic, conventional, and integrated management. *HortScience,* 41**,** 99-107.

PECK, G. M., MERWIN, I. A., WATKINS, C. B., CHAPMAN, K. W. & PADILLA-ZAKOUR, O. I. 2009. Maturity and quality of 'Liberty' apple fruit under integrated and organic fruit production systems are similar. *HortScience,* 44**,** 1382-1389.

PÉREZ-RUIZ, M., SLAUGHTER, D., GLIEVER, C. & UPADHYAYA, S. 2012. Automatic GPS-based intra-row weed knife control system for transplanted row crops. *Computers and Electronics in Agriculture,* 80**,** 41-49.

PERKOWSKI, J., WIWART, M., BUSKO, M., LASKOWSKA, M., BERTHILLER, F., KANDLER, W. & KRSKA, R. 2007. Fusarium toxins and total fungal biomass indicators in naturally contaminated wheat samples from north-eastern Poland in 2003. *Food Additives and Contaminants,* 24**,** 1292-1298.

PETTERSSON, P., SALOMONSSON, L. & NORDKVIST, E. 1998. Differences in botanical and chemical composition of forage from organic and conventional leys: a survey at farm field level. *Acta Agriculturae Scandinavica. Section B. Soil and Plant Science,* 48**,** 18-25.

PFIFFNER, L. & LUKA, H. 2003. Effects of low-input farming systems on carabids and epigeal spiders - a paired farm approach. (Special issue: Management of biodiversity in agroecosystems). *Basic and Applied Ecology,* 4**,** 117-127.

PFIFFNER, L. & NIGGLI, U. 1996. Effects of bio-dynamic, organic and conventional farming on ground beetles (Col Carabidae) and other epigaeic arthropods in winter wheat. *Biological Agriculture & Horticulture,* 12**,** 353-364.

PICCHI, V., MIGLIORI, C., SCALZO, R. L., CAMPANELLI, G., FERRARI, V. & CESARE, L. F. D. 2012. Phytochemical content in organic and conventionally grown Italian cauliflower. *Food Chemistry,* 130**,** 501-509.

PIEMONTESE, L., SOLFRIZZO, M. & VISCONTI, A. 2005. Occurrence of patulin in conventional and organic fruit products in Italy and subsequent exposure assessment. *Food Additives and Contaminants,* 22**,** 437-442.

PIQUE, E., VARGAS-MURGA, L., GOMEZ-CATALAN , J., LLOBET, J.M. 2013. Occurrence of patulin in organic and conventional apple juice. Risk assessment. *Recent Advances in Pharmaceutical Sciences* III, 2013: 131-144. ISBN: 978-81-7895-605-3 Editors: D Munoz-Torrero, A Cortes and EL Marino.

POLLNAC, F. W., REW, L. J., MAXWELL, B. D. & MENALLED, F. D. 2008. Spatial patterns, species richness and cover in weed communities of organic and conventional no-tillage spring wheat systems. *Weed Research,* 48**,** 398-407.

PONCE, C., BRAVO, C., LEON, D. G., MAGANA, M. & ALONSO, J. C. 2011. Effects of organic farming on plant and arthropod communities: A case study in Mediterranean dryland cereal. *Agriculture Ecosystems & Environment,* 141**,** 193-201.

PONTI, L., ALTIERI, M. A. & GUTIERREZ, A. P. 2007. Effects of crop diversification levels and fertilization regimes on abundance of Brevicoryne brassicae (L.) and its parasitization by Diaeretiella rapae (M'Intosh) in broccoli. *Agricultural and Forest Entomology,* 9**,** 209-214.

POVEDA, K., STEFFAN-DEWENTER, I., SCHEU, S. & TSCHARNTKE, T. 2006. Belowground effects of organic and conventional farming on aboveground plant-herbivore and plant-pathogen interactions. *Agriculture Ecosystems & Environment,* 113**,** 162-167.

POVOLNY, P. 1995. Influence of exposure to light and cultivation system on resistance to Phoma foveata and Fusarium solani var. coeruleum in potato tubers - a pilot study. *Swedish Journal of Agricultural Research,* 25**,** 47-50.

POWER, E. F., KELLY, D. L. & STOUT, J. C. 2012. Organic Farming and Landscape Structure: Effects on Insect-Pollinated Plant Diversity in Intensively Managed Grasslands. *Plos One,* 7.

POWER, E. F. & STOUT, J. C. 2011. Organic dairy farming: impacts on insect-flower interaction networks and pollination. *Journal of Applied Ecology,* 48**,** 561-569.

PRIETO-BENITEZ, S. & MENDEZ, M. 2011. Effects of land management on the abundance and richness of spiders (Araneae): A meta-analysis. *Biological Conservation,* 144**,** 683-691.

PURTAUF, T., ROSCHEWITZ, I., DAUBER, J., THIES, C., TSCHARNTKE, T. & WOLTERS, V. 2005. Landscape context of organic and conventional farms: influences on carabid beetle diversity. *Agriculture, Ecosystems & Environment,* 108**,** 165-174.

PUSSEMIER, L., LARONDELLE, Y., CARLOS, V. P. C. & HUYGHEBAERT, A. 2006a. Chemical safety of conventionally and organically produced foodstuffs: a tentative comparison under Belgian conditions. *Food Control,* 17**,** 14-21.

PUSSEMIER, L., PIERARD, J. Y., ANSELME, M., TANGNI, E. K., MOTTE, J. C. & LARONDELLE, Y. 2006b. Development and application of analytical methods for the determination of mycotoxins in organic and conventional wheat. *Food Additives and Contaminants,* 23**,** 1208-1218.

RAFFAELLI, M., FONTANELLI, M., FRASCONI, C., SORELLI, F., GINANNI, M. & PERUZZI, A. 2011. Physical weed control in processing tomatoes in Central Italy. *Renewable Agriculture and Food Systems,* 26**,** 95-103.

RAJASHEKAR, C. B., OH, M. & CAREY, E. E. 2012. Organic crop management enhances chicoric acid content in lettuce. *Food and Nutrition Sciences,* 3**,** 1296-1302.

RASMUSSEN, I. A., ASKEGAARD, M., OLESEN, J. E. & KRISTENSEN, K. 2006. Effects on weeds of management in newly converted organic crop rotations in Denmark. *Agriculture, ecosystems & environment,* 113**,** 184-195.

RASMUSSEN, K. & RASMUSSEN, J. 2000. Barley seed vigour and mechanical weed control. *WEED RESEARCH-OXFORD-,* 40**,** 219-230.

REBARZ, K., BOROWCZAK, F. & GRZES, S. 2006. Weed infestation of potatoes depending on irrigation and cultivation system. *Progress in Plant Protection,* 46**,** 219-222.

REDDERSEN, J. 1997. The arthropod fauna of organic versus conventional cereal fields in Denmark. *Biological Agriculture and Horticulture,* 15**,** 61-71.

REIG, G., LARRIGAUDIERE, C. & SORIA, Y. 2007. Effects of organic and conventional growth management on apple fruit quality at harvest. *Acta Horticulturae,* 737**,** 61-65.

REMBIALKOWSKA, E. 1999. Comparison of the contents of nitrates, nitrites, lead, cadmium and vitamin C in potatoes from conventional and ecological farms. *Polish Journal of Food and Nutrition Sciences (Poland). Formerly: Acta Alimentaria Polonica,* 8**,** 17-26.

REMBIALKOWSKA, E. 2004. The impact of organic agriculture on food quality. *Agricultura,* 3**,** 19-26.
REMBIAŁKOWSKA, E., ZAŁĘCKA, A., BADOWSKI, M. & PLOEGER, A. 2012. The Quality of Organically Produced Food.
RHAINDS, M., KOVACH, J. & ENGLISH-LOEB, G. 2002. Impact of strawberry cultivar and incidence of pests on yield and profitability of strawberries under conventional and organic management systems. *Biological Agriculture & Horticulture,* 19**,** 333-353.
RITIENI, A. 2003. Patulin in Italian commercial apple products. *Journal of Agricultural and Food Chemistry* 51, 6086-6090.
RODRIGUEZ, J., RIOS, D., RODRIGUEZ, E. & DIAZ, C. 2010. Physico-chemical changes during ripening of conventionally, ecologically and hydroponically cultivated Tyrlain (TY 10016) tomatoes. *International Journal of Agricultural Research,* 5**,** 897-906.
ROINILA, P., VÄISÄNEN, J., GRANSTEDT, A. & KUNTTU, S. 2003. Effects of different organic fertilization practices and mineral fertilization on potato quality. *Biological agriculture & horticulture,* 21**,** 165-194.
ROMERO, A., CHAMORRO, L. & SANS, F. X. 2008. Weed diversity in crop edges and inner fields of organic and conventional dryland winter cereal crops in NE Spain. *Agriculture Ecosystems & Environment,* 124**,** 97-104.
ROOSE, M., KAHL, J. & PLOEGER, A. 2009. Influence of the farming system on the xanthophyll content of soft and hard wheat. *Journal of Agricultural and Food Chemistry,* 57**,** 182-188.
ROSCHEWITZ, I., GABRIEL, D., TSCHARNTKE, T. & THIES, C. 2005a. The effects of landscape complexity on arable weed species diversity in organic and conventional farming. *Journal of Applied Ecology,* 42**,** 873-882.
ROSCHEWITZ, I., HUCKER, M., TSCHARNTKE, T. & THIES, C. 2005b. The influence of landscape context and farming practices on parasitism of cereal aphids. *Agriculture Ecosystems & Environment,* 108**,** 218-227.
ROSS, S. M., KING, J. R., IZAURRALDE, R. C. & O'DONOVAN, J. T. 2001. Weed suppression by seven clover species. *Agronomy Journal,* 93**,** 820-827.
ROSSI, F., BERTUZZI, T., COMIZZOLI, S., TURCONI, G., ROGGI, C., PAGANI, M., CRAVEDI, P. & PIETRI, A. 2006. Preliminary survey on composition and quality of conventional and organic wheat. *Italian Journal of Food Science,* 18**,** 355-366.
ROSSI, F., GODANI, F., BERTUZZI, T., TREVISAN, M., FERRARI, F. & GATTI, S. 2008. Health-promoting substances and heavy metal content in tomatoes grown with different farming techniques. *European Journal of Nutrition,* 47**,** 266-272.
ROTH, E., BERNA, A., BEULLENS, K., LAMMERTYN, J., SCHENK, A. & NICOLAI, B. 2007. Postharvest quality of integrated and organically produced apple fruit. *Acta Horticulturae,* 737**,** 39-45.
ROTH, E., BERNA, A. Z., BEULLENS, K., SCHENK, A., LAMMERTYN, J. & NICOLAI, B. 2005. Comparison of taste and aroma of integrated and organic apple fruit. *Communications in Agricultural and Applied Biological Sciences,* 70**,** 225-229.
ROUSSOS, P. A., TRIANTAFILLIDIS, A. & KEPOLAS, E. 2012. Strawberry fruit production and quality under conventional, integrated and organic management. *Acta Horticulturae,* 926**,** 541-546.
RUNDLOF, M., NILSSON, H. & SMITH, H. G. 2008. Interacting effects of farming practice and landscape context on bumblebees. *Biological Conservation,* 141**,** 417-426.
RUNNO-PAURSON, E., WILLIAMS, I. H., METSPALU, L., KAART, T. & MÄND, M. 2013. Current potato varieties are too susceptible to late blight to be grown without

chemical control under North-East European conditions. *Acta Agriculturae Scandinavica, Section B–Soil & Plant Science,* 63**,** 80-88.
RYDBERG, N. T. & MILBERG, P. 2000. A survey of weeds in organic farming in Sweden. *Biological Agriculture & Horticulture,* 18**,** 175-185.
SAASTAMOINEN, M., HIETANIEMI, V., PIHLAVA, J. M., EUROLA, M., KONTTURI, M., TUURI, H., NISKANEN, M. & KANGAS, A. 2004. beta -Glucan contents of groats of different oat cultivars in official variety, in organic cultivation, and in nitrogen ferilization trials in Finland. *Agricultural and Food Science,* 13**,** 68-79.
SABLANI, S. S., ANDREWS, P. K., DAVIES, N. M., WALTERS, T., SAEZ, H., SYAMALADEVI, R. M. & MOHEKAR, P. R. 2010. Effect of thermal treatments on phytochemicals in conventionally and organically grown berries. *Journal of the Science of Food and Agriculture,* 90**,** 769-778.
SALONEN, J. & HYVONEN, T. 2002. Perennial weeds in conventional and organic cropping of spring cereals in Finland. *Zeitschrift Fur Pflanzenkrankheiten Und Pflanzenschutz-Journal of Plant Diseases and Protection***,** 519-525.
SALONEN, J., HYVONEN, T. & JALLI, H. 2001a. Weed flora in organically grown spring cereals in Finland. *Agricultural and Food Science in Finland,* 10**,** 231-242.
SALONEN, J., HYVONEN, T. & JALLI, H. 2001b. Weeds in spring cereal fields in Finland - a third survey. *Agricultural and Food Science in Finland,* 10**,** 347-364.
SALONEN, J., HYVONEN, T. & JALLI, H. 2005. Weed flora and weed management of field peas in Finland. *Agricultural and Food Science,* 14**,** 189-201.
SALONEN, J., HYVONEN, T. & JALLI, H. 2011. Composition of weed flora in spring cereals in Finland - a fourth survey. *Agricultural and Food Science,* 20**,** 245-261.
SALONEN, J., HYVONEN, T., KASEVA, J. & JALLI, H. 2013. Impact of changed cropping practices on weed occurrence in spring cereals in Finland - a comparison of surveys in 1997-1999 and 2007-2009. *Weed Research,* 53**,** 110-120.
SAWICKA, B. 2003. Quality of potato cultivated under the ecological and integrated production system. *Sodininkyste ir Darzininkyste,* 22**,** 10-20.
SCALZO, R. L., IANNOCCARI, T., GENNA, A., CESARE, L. F. D., VISCARDI, D., FERRARI, V. & CAMPANELLI, G. 2008. Organic vs. conventional field trials: the effect on cauliflower quality. *In:* NEUHOFF, D., HALBERG, N., ALFOLDI, T., LOCKERETZ, W., THOMMEN, A., RASMUSSEN, I. A., HERMANSEN, J., VAARST, M., LUECK, L., CAPORALI, F., JENSEN, H. H., MIGLIORINI, P. & WILLER, H. (eds.). Bonn: Cultivating the future based on science Volume 2, International Society of Organic Agricultural Research (ISOFAR).
SCHMIDT, M. H., ROSCHEWITZ, I., THIES, C. & TSCHARNTKE, T. 2005. Differential effects of landscape and management on diversity and density of ground-dwelling farmland spiders. *Journal of Applied Ecology,* 42**,** 281-287.
SCHOLLENBERGER, M., JARA, H. T., SUCHY, S., DROCHNER, W. & MULLER, H. M. 2002. Fusarium toxins in wheat flour collected in an area in southwest Germany. *International Journal of Food Microbiology,* 72**,** 85-89.
SCHROTER, L. & IRMLER, U. 2013. Organic cultivation reduces barrier effect of arable fields on species diversity. *Agriculture Ecosystems & Environment,* 164**,** 176-180.
SCHNEWEIS, I., MEYER, K., RITZMANN, M., HOFFMANN, P., DEMPFLE, L. & BAUER, J. 2005. Influence of organically or conventionally produced wheat on health, performance and mycotoxin residues in tissues and bile of growing pigs. *Archives of Animal Nutrition,* 59**,** 155-163.
SEAN CLARK, M. 1999. Ground beetle abundance and community composition in conventional and organic tomato systems of California's Central Valley. *Applied Soil Ecology,* 11**,** 199-206.

SHEWRY, P. 2009. Wheat. *Journal of experimental Botany,* 60**,** 1537-1553.

SHEWRY, P. R. 2011. Effects of nitrogen and sulfur nutrition on grain composition and properties of wheat and related cereals. *The Molecular and Physiological Basis of Nutrient Use Efficiency in Crops***,** 103-120.

SJURSEN, H. 2001. Change of the weed seed bank during the first complete six-course crop rotation after conversion from conventional to organic farming. *Biological Agriculture & Horticulture,* 19**,** 71-90.

SJURSEN, H., BRANDSÆTER, L. O. & NETLAND, J. 2012. Effects of repeated clover undersowing, green manure ley and weed harrowing on weeds and yields in organic cereals. *Acta Agriculturae Scandinavica, Section B-Soil & Plant Science,* 62**,** 138-150.

SKUPIEN, K., OCHMIAN, I., GRAJKOWSKI, J. & KRZYWY-GAWRONSKA, E. 2011. Nutrients, antioxidants, and antioxidant activity of organically and conventionally grown raspberries. *Journal of Applied Botany and Food Quality-Angewandte Botanik,* 84**,** 85-89.

SMITH-SPANGLER, C., BRANDEAU, M. L., HUNTER, G. E., CLAY BAVINGER, J., PEARSON, M., ESCHBACH, P. J., SUNDARAM, V., LIU, H., SCHIRMER, P., STAVE, C., OLKIN, I. & BRAVATA, D. M. 2012b. Are organic foods safer or healthier than conventional alternatives?: A systematic review. *Annals of Internal Medicine,* 157**,** 348-366.

SOLTOFT, M., BYSTED, A., MADSEN, K. H., MARK, A. B., BUGEL, S. G., NIELSEN, J. & KNUTHSEN, P. 2011. Effects of organic and conventional growth systems on the content of carotenoids in carrot roots, and on intake and plasma status of carotenoids in humans. *Journal of the Science of Food and Agriculture,* 91**,** 767-775.

SOLTOFT, M., NIELSEN, J., LAUREN, K. H., HUSTED, S., HALEKOH, U. & KNUTHSEN, P. 2010a. Effects of Organic and Conventional Growth Systems on the Content of Flavonoids in Onions and Phenolic Acids in Carrots and Potatoes. *Journal of Agricultural and Food Chemistry,* 58**,** 10323-10329.

SOLTOFT, M., NIELSEN, J., LAURSEN, K. H., HUSTED, S., HALEKOH, U. & KNUTHSEN, P. 2010b. Effects of organic and conventional growth systems on the content of flavonoids in onions and phenolic acids in carrots and potatoes. *Journal of Agricultural and Food Chemistry,* 58**,** 10323-10329.

SORIA, Y., SCHOTSMANS, W., REIG, G. & LARRIGAUDIERE, C. 2010. A comparative study of 'Golden Delicious' and 'Fuji' apples produced by organic and integrated systems in the North-East of Spain. *Acta Horticulturae,* 873**,** 197-206.

SPADARO, D., CIAVORELLA, A., FRATI, S., GARIBALDI, A. & GULLINO, M. L. 2007. Incidence and level of patulin contamination in pure and mixed apple juices marketed in Italy. *Food Control,* 18**,** 1098-1102.

SPORNBERGER, A., STEFFEK, R., JEZIK, K. & STICH, K. 2011. Long-Term Effect of Different Fertilizing and Plant Protection Systems (Organic vs. Conventional) on Field Characteristics of Strawberries (Fragaria x ananassa). *Biological Agriculture & Horticulture,* 27**,** 179-188.

STALEY, J. T., STEWART-JONES, A., POPE, T. W., WRIGHT, D. J., LEATHER, S. R., HADLEY, P., ROSSITER, J. T., VAN EMDEN, H. F. & POPPY, G. M. 2010. Varying responses of insect herbivores to altered plant chemistry under organic and conventional treatments. *Proceedings of the Royal Society B-Biological Sciences,* 277**,** 779-786.

STRACKE, B. A., EITEL, J., WATZL, B., MADER, P. & RUFER, C. E. 2009a. Influence of the production method on phytochemical concentrations in whole wheat (Triticum aestivum L.): a comparative study. *Journal of Agricultural and Food Chemistry,* 57**,** 10116-10121.

STRACKE, B. A., RUFER, C. E., WEIBEL, F. P., BUB, A. & WATZL, B. 2009b. Three-year comparison of the polyphenol contents and antioxidant capacities in organically and conventionally produced apples (Malus domestica Bork. cultivar 'Golden Delicious'). *Journal of Agricultural and Food Chemistry,* 57**,** 4598-4605.

STROBEL, E., AHRENS, P., HARTMANN, G., KLUGE, H. & JEROCH, H. 2001. Contents of substances in wheat, rye and oats at cultivation under conventional and the conditions of organic farming. *Bodenkultur,* 52**,** 221-231.

SUTERSKA, A. M., ZIELINSKA, K. J., GRZYBOWSKI, R. A., STECKA, K. M., MIECZNIKOWSKI, A. H. & KUPRYS, M. P. 2009. Effect of the selected strains from Lactobacillus genus on the limitation of mould and ochratoxin a contamination of silages from meadow cover.

TAMM, I., TAMM, U. & INGVER, A. 2009. Spring cereals performance in organic and conventional cultivation. *Agronomy Research***,** 522-527.

TAROZZI, A., COCCHIOLA, M., D'EVOLI, L., FRANCO, F., HRELIA, P., GABRIELLI, P., LUCARINI, M., AGUZZI, A. & LOMBARDI-BOCCIA, G. 2010. Fruit attributes, phenolic compounds, antioxidant and antiproliferative activity of strawberries (Fragaria ananassa, 'Favette') grown by biodynamic and conventional agriculture methods. *Acta Horticulturae,* 873**,** 289-294.

THOMSEN, M.G**.**, BRANDSÆTER, L.O. & FYKSE, H. 2013. Regeneration of Canadian thistle (C. arvense) from Intact Roots and Root Fragments at Different Soil Depths. *Weed Science,* 61, 277–282.

TONUTARE, T., MOOR, U., MOLDER, K. & POLDMA, P. 2009. Fruit composition of organically and conventionally cultivated strawberry 'Polka'. *Agronomy Research***,** 755-760.

TSCHARNTKE, T., KLEIN, A. M., KRUESS, A., STEFFAN- DEWENTER, I. & THIES, C. 2005. Landscape perspectives on agricultural intensification and biodiversity–ecosystem service management. *Ecology letters,* 8**,** 857-874.

TSIAFOULI, M. A., ARGYROPOULOU, M. D., STAMOU, G. P. & SGARDELIS, S. P. 2006. Soil nematode biodiversity in organic and conventional agroecosystems of Northern Greece. *Russian Journal of Nematology,* 14**,** 159-169.

TURMEL, M. S., ENTZ, M. H., BAMFORD, K. C. & MARTENS, J. R. T. 2009. The influence of crop rotation on the mineral nutrient content of organic vs. conventionally produced wheat grain: Preliminary results from a long-term field study. *Canadian Journal of Plant Science,* 89**,** 915-919.

TWARUŻEK, M., BŁAJET-KOSICKA, A., WENDA-PIESIK, A., PAŁUBICKI, J. & GRAJEWSKI, J. 2013. Statistical comparison of< i> Fusarium</i> mycotoxins content in oat grain and related products from two agricultural systems. *Food Control,* 34**,** 291-295.

ULBER, L., STEINMANN, H. H., KLIMEK, S. & ISSELSTEIN, J. 2009. An on-farm approach to investigate the impact of diversified crop rotations on weed species richness and composition in winter wheat. *Weed Research,* 49**,** 534-543.

VALAVANIDIS, A., VLACHOGIANNI, T., PSOMAS, A., ZOVOILI, A. & SIATIS, V. 2009. Polyphenolic profile and antioxidant activity of five apple cultivars grown under organic and conventional agricultural practices. *International Journal of Food Science & Technology,* 44**,** 1167-1175.

VAN BRUGGEN, A. H. C. 1995. PLANT-DISEASE SEVERITY IN HIGH-INPUT COMPARED TO REDUCED-INPUT AND ORGANIC FARMING SYSTEMS. *Plant Disease,* 79**,** 976-984.

VAN BUEREN, E. T. L., JONES, S. S., TAMM, L., MURPHY, K. M., MYERS, J. R., LEIFERT, C. & MESSMER, M. M. 2011. The need to breed crop varieties suitable

for organic farming, using wheat, tomato and broccoli as examples: a review. (Special Issue: Improving production efficiency, quality and safety in organic and 'low-input' food supply chains.). *NJAS Wageningen Journal of Life Sciences,* 58**,** 193-205.
VAN BUEREN, E. T. L., STRUIK, P. C. & JACOBSEN, E. 2003. Organic propagation of seed and planting material: an overview of problems and challenges for research. *NJAS Wageningen Journal of Life Sciences,* 51**,** 263-277.
VANOVA, M., KLEM, K., MISA, P., MATUSINSKY, P., HAJSLOVA, J. & LANCOVA, K. 2008. The content of Fusarium mycotoxins, grain yield and quality of winter wheat cultivars under organic and conventional cropping systems.
VARIS, E., PIETILAE, L. & KOIKKALAINEN, K. 1996. Comparison of conventional, integrated and organic potato production in field experiments in Finland. *Acta Agriculturae Scandinavica. Section B. Soil and Plant Science,* 46**,** 41-48.
VEBERIC, R., TROBEC, M., HERBINGER, K., HOFER, M., GRILL, D. & STAMPAR, F. 2005. Phenolic compounds in some apple (Malus domestica Borkh) cultivars of organic and integrated production. *Journal of the Science of Food and Agriculture,* 85**,** 1687-1694.
VELEMA, 2004. Challenges and opportunities in organic seed production. *Proceedings of the First World Conference on Organic Seed*. Challenges and Opportunities for Organic Agriculture and the Seed Industry, July 5-7, 2004, FAO Headquarters, Rome, Italy, p 4-5.
VEROMANN, E., SAARNIIT, M., KEVVAI, R. & LUIK, A. 2009. Effect of crop management on the incidence of Meligethes aeneus Fab. and their larval parasitism rate in organic and conventional winter oilseed rape. *Agronomy Research***,** 548-554.
VERSARI, A., PARPINELLO, G. P. & MATTIOLI, A. U. 2007. Survey of patulin contamination in Italian apple juices from organic and conventional agriculture. *Journal of Food Technology,* 5**,** 143-146.
VIDAL, A., MARIN, S., RAMOS, A. J., CANO-SANCHO, G. & SANCHIS, V. 2013. Determination of aflatoxins, deoxynivalenol, ochratoxin A and zearalenone in wheat and oat based bran supplements sold in the Spanish market. *Food and Chemical Toxicology,* 53**,** 133-138.
VRCEK, V. & VRCEK, I. V. 2012. Metals in organic and conventional wheat flours determined by an optimised and validated ICP-MS method. *International Journal of Food Science & Technology,* 47**,** 1777-1783.
WALSH, C. S., OTTESEN, A. R., NEWELL, M. J., HANSON, J. C. & LEONE, E. H. 2011. The effect of organic and conventional management programs on apple and Asian pear tree growth, productivity, expenses and revenues in a hot, humid climate. *Acta Horticulturae,* 903**,** 665-672.
WARMAN, P. R. & HAVARD, K. A. 1998. Yield, vitamin and mineral contents of organically and conventionally grown potatoes and sweet corn. *Agriculture, Ecosystems and Environment,* 68**,** 207-216.
WEIBEL, F. P., BICKEL, R., LEUTHOLD, S. & ALFOLDI, T. 2000. Are organically grown apples tastier and healthier? A comparative field study using conventional and alternative methods to measure fruit quality. *Acta Horticulturae,* 517**,** 417-426.
WEIBULL, A. C. & OSTMAN, O. 2003. Species composition in agroecosystems: the effect of landscape, habitat, and farm management. *Basic and Applied Ecology,* 4**,** 349-361.
WEIBULL, A. C., OSTMAN, O. & GRANQVIST, A. 2003. Species richness in agroecosystems: the effect of landscape, habitat and farm management. *Biodiversity and Conservation,* 12**,** 1335-1355.

WISNIOWSKA-KIELIAN, B. & KLIMA, K. 2006. Comparison of macroelement contents in the winter wheat grain from organic and conventional farms. *Journal of Research and Applications in Agricultural Engineering,* 51**,** 204-208.

WITCZAK, A. & ABDEL-GAWAD, H. 2012. Comparison of organochlorine pesticides and polychlorinated biphenyls residues in vegetables, grain and soil from organic and conventional farming in Poland. *Journal of Environmental Science and Health,* 47**,** 343-354.

WOESE, K., LANGE, D., BOESS, C. & BOGL, K. W. 1997. A comparison of organically and conventionally grown foods - results of a review of the relevant literature. *Journal of the Science of Food and Agriculture,* 74**,** 281-293.

WOJDYLO, A., OSZMIANSKI, J., TELESZKO, M. & SOKÓL-LETOWSKA, A. 2013. Composition and quantification of major polyphenolic compounds, antioxidant activity and colour properties of quince and mixed quince jams. *International journal of food sciences and nutrition,* 64**,** 749-756.

WOLFE, M. S., BARESEL, J. P., DESCLAUX, D., GOLDRINGER, I., HOAD, S., KOVACS, G., LOSCHENBERGER, F., MIEDANER, T., OSTERGARD, H. & BUEREN, E. T. L. V. 2008. Developments in breeding cereals for organic agriculture. *Euphytica,* 163**,** 323-346.

WORTHINGTON, V. 2001. Nutritional quality of organic versus conventional fruits, vegetables, and grains. *Journal of Alternative and Complementary Medicine,* 7**,** 161-173.

WRZODAK, A., SZWEJDA-GRZYBOWSKA, J., ELKNER, K. & BABIK, I. 2012. Comparison of the nutritional value and storage life of carrot roots from organic and conventional cultivation. *Vegetable Crops Research Bulletin,* 76**,** 137-150.

WSZELAKI, A. L., DELWICHE, J. F., WALKER, S. D., LIGGETT, R. E., SCHEERENS, J. C. & KLEINHENZ, M. D. 2005. Sensory quality and mineral and glycoalkaloid concentrations in organically and conventionally grown redskin potatoes (Solanum tuberosum). *Journal of the Science of Food and Agriculture,* 85**,** 720-726.

XU, Y., AN, D., LI, H. & XU, H. 2011. Review: Breeding wheat for enhanced micronutrients. *Canadian Journal of Plant Science,* 91**,** 231-237.

YOUNG, J. E., ZHAO, X., CAREY, E. E., WELTI, R., YANG, S. S. & WANG, W. Q. 2005. Phytochemical phenolics in organically grown vegetables. *Molecular Nutrition & Food Research,* 49**,** 1136-1142.

YOUNG, S. L. & PIERCE, F. J. 2014. Automation: The Future of Weed Control in Cropping Systems.

ZALLER, J. 2004. Ecology and non-chemical control of Rumex crispus and R. obtusifolius (Polygonaceae): a review. *Weed research,* 44**,** 414-432.

ZAPATA, P. J., TUCKER, G. A., VALERO, D. & SERRANO, M. 2013. Quality parameters and antioxidant properties in organic and conventionally grown broccoli after pre-storage hot water treatment. *Journal of the Science of Food and Agriculture,* 93**,** 1140-1146.

ZARZYNSKA, K. & SZUTKOWSKA, M. 2013. Developmental differences, yield and late blight (Phytophthora infestans) infection of potato plants grown under organic and conventional systems. *Journal of Agricultural Science and Technology A,* 3**,** 281-289.

ZELLNER, M., KEIL, S., BENKER, M. 2011. Latent infection rate of potato seed tubers with *Phytophthora infestans* (Mont.) de Bary – an underestimated problem. *Journal fur Kulturpflanzen*, 63, 13-16.

ZUCHOWSKI, J., JONCZYK, K., PECIO, L. & OLESZEK, W. 2011. Phenolic acid concentrations in organically and conventionally cultivated spring and winter wheat. *Journal of the Science of Food and Agriculture,* 91**,** 1089-1095.